FABRIC

Feasibility analysis and development of on-road charging solutions for future electric vehicles

Assessment of the technical feasibility of ICT and charging solutions

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LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
ANPR	Automatic Number Plate Recognition
API	Application Programming Interface
AVI	Automatic Vehicle Identification
BPEL	(Web Services) Business Process Execution Language
BR	Barcode Reader
CAN	Controller Area Network
CEP	Complex Event Processor
CHADeMO	*CHArge de MOve*, equivalent to *charge for moving*
CO2	Carbon Dioxide
CWD	Charge While Driving
DC	Direct Current
DGPS	Differential Global Positioning System
DMV	Driver Motor Vehicle
DSL	Domain Specific Language
DSO	Distribution System Operator
DXX.X	Deliverable XX.X
EETS	European Electronic Toll Service
EMAID	e-Mobility Account Identifier
EMC	Electromagnetic Compatibility
EMP	FABRIC Electric Mobility Platform
EMV	Europay, MasterCard and Visa
ESB	Enterprice Service Bus
ESRI	Environmental Systems Research Institute
ERG	External Reference Group
ETC	Electronoc Tool Connection
EV	Electric Vehicle
EVCC	Electric Vehicle Communication Controller
EVDC	Electrical Vehicle Dynamic Charging
EXI	Efficient XML Interchange
FABRIC	FeAsiBility analysis and development of on-Road chargIng solutions for future electric vehiCles
FTP	File Transfer Protocol
GIS	Geographic Information System
GPRS	General Packet Radio Service
GSM	Global System for Mobile communication
HDV	Heavy Duty Vehicle
HMI	Human-Machine Interface

I2I	Infrastructure to Infrastructure
ICT	Information and Communication Technology
ICCP	Inter Control-Center Communications Protocol
IDE	Integrated Development Environment
IOC	Intelligent Operations Center
IP	Internet Protocol
IPV	Induction Powered Vehicle
ISM	Industrial, Scientific and Medical Band
ISO	International Organization for Standardization
ITS	Intelligent Transportation System
JMS	Java Message Service
KAIST	Korea Advanced Institute of Science & Technology
KPI	Key Performance Indicator
LBC	Load Balancing Control
LDV	Light Duty Vehicle
LTE	Long Term Evolution
MAC	Media Access Control
MIT	Massachusetts Institute of Technology
NFC	Near Field Communication
NIST	National Institute of Standards and Technology
OBU	On-board Unit
OCR	Optical Character Recognition
ODE	Orchestration Director Engine
OEM	Original Equipment Manufacturers
OLEV	Online Electric Vehicle
OO	Object-Oriented
OSGi	Open Services Gateway Initiative
OSI	Open Systems Interconnection
OSM	OpenStreetMap
PIN	Personal Identification Number
PLC	Power Line Communication
POD	Point of Distribution
RADEF	Road Administration Data Exchange
RES	Renewable Energy Sources
REST	Representational State Transfer (REST)
RF	Radio Frequency
RFID	Radio Frequency Identification
RSU	Road-side Unit
RTP	Real-Time Protocol
SDK	Software Development Kit

SE	Service Engine
SECC	Supply Equipment Communication Controller
SET	Secure Electronic Transaction
SLA	Service Level Agreement
SOA	Service-Oriented Architecture
SOAP	Simple Object Access Protocol
SoC	Separation of Concerns
SP	Sub-Project
SSL	Secured Socket Layer
TCP	Transmission Control Protocol
TEN-T	Trans-European Networks – Transport
TMS	Traffic Management System
TRL	Technology Readiness Level
UC	Use Case
UDDI	Universal Description, Discovery and Integration
UML	Unified Modelling Language
V2G	Vehicle to Grid
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VPN	Virtual Private Network
WP	Work Package
WPT	Wireless Power Transfer
WSDL	Web Services Description Language

REVISION CHART AND HISTORY LOG

REV	DATE	REASON
0.1	15/05/2014	Deliverable structure, Table of Contents and first contents
0.2	10/07/2014	Contributions from several partners
0.3	28/07/2014	Several updates
0.4	31/07/2014	Several updates
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1.0	13/11/2014	Final Version

EXECUTIVE SUMMARY

The main purpose of this document is to assess several technologies that could be used for the implementation of the FABRIC platform. The target audience is mainly the same FABRIC partners responsible for the implementation of this platform, as they should take this document as an input for the selection of existing systems and ICT modules that could be used as is or adapted to realize the envisioned system.

With this objective in mind, the next steps have been followed: first of all, a methodology has been proposed in order to build a homogenous analysis and assessment of the technologies under study. An important aspect of this methodology is the specification of a set of assessment criteria that will be evaluated against each proposed technology. So, for the assessment of charging solutions, the following criteria have been considered:

- Performance of the solution (low, medium or high)
- EMC issue (low disturbances or high disturbances)
- Closeness to market (low effort or high effort)
- Cost (low, medium or high)
- Maturity (low, medium or high)
- Safety (not safe, enough safe or very safe)
- Scalability in terms of vehicles and road coverage (not scalable or scalable)

While, for the assessment of ICT Solutions, it has been defined:

- Implementation of the solution (easy, medium or difficult)
- Interoperability between different car makers (easy, medium or difficult)
- Cost of the ICT tools (low, medium or high)
- Security (low, medium or high)
- Safety (low, medium or high)
- Efficiency (low, medium or high)
- Maintenance (easy, medium or difficult)
- Usability (easy, medium or difficult)
- Closeness to market (low effort to market or high effort to market)

At the same time, several technology categories have been defined for each functional component included in the preliminary high level architecture of FABRIC system (Please, refer to FABRIC Final use cases [2]):

- FABRIC Electric Mobility Platform
- EV Identification technologies
- Routing
- Connected Car and HMI

- Charging Infrastructure Operator and Load Balancing Control
- Infrastructure Charging Control
- Charging assistance
- Payment Interfaces
- Road Operator interface
- DSO and Retailer Modules / Interfaces

Inside each category, it has been proposed, reviewed and analysed several existing alternative technologies, from commercial sources, state of the art, internal developments of the FABRIC partners or other related initiatives. The main conclusion of this analysis is the assessment of the different technologies proposed, in terms of suitability for the implementation of the FABRIC system. It is important to highlight that this assessment does not imply a final selection for the implementation phase but a guideline of the technologies for each of them.

Table 1: Summary table of charging solutions

	Overall assessment
POLITO CWD WPT solution	**Suitable for FABRIC**
Saet Spa- Induction powered vehicle (IPV)	**Suitable for FABRIC**
Online Electric Vehicle (OLEV)	**Highly suitable for FABRIC**
Conductix Wampfler IPT	**Suitable for FABRIC**
Plugless Power	**Suitable for FABRIC**
Witricity	**Suitable for FABRIC**
Siemens eHighway	**Not suitable for FABRIC**

Table 2: Summary table of ICT solutions

Technology group	**Technology**	**Overall assessment**
EMP[1]. Case 1: Basic Technologies.	WSO2 ESB	**Highly suitable for FABRIC**

[1] FABRIC Electric Mobility Platform

Technology group	Technology	Overall assessment
Service Bus	Open ESB	**Suitable for FABRIC**
	ServiceMix	**Suitable for FABRIC**
EMP. Case 1: Basic Technologies. Process Management & Service Orchestration	Apache ODE	**Suitable for FABRIC**
	WSO2 Business Process Server	**Highly suitable for FABRIC**
EMP. Case 1: Basic Technologies. Complex Event Processing	WSO2 CEP	**Highly suitable for FABRIC**
	Esper	**Suitable for FABRIC**
EMP. Case 2: Full Technologies	IBM Platform: IOC	**Suitable for FABRIC**
Identification	Barcode reader	**Not suitable for FABRIC**
	ANPR	**Highly suitable for FABRIC**
	RFID	**Suitable for FABRIC (Static recharge Scenario)**
	DSRC	**Highly suitable for FABRIC**
Routing	Google Maps Web services	**Suitable for FABRIC**
	Bing Maps	**Suitable for FABRIC**

Technology group	Technology	Overall assessment
	ARCGIS	**Suitable for FABRIC**
	HERE Maps	**Suitable for FABRIC**
	MapQuest	**Highly suitable for FABRIC**
Connected Car and HMI	MirrorLink	**Suitable for FABRIC**
	CarPlay	**Suitable for FABRIC**
	Open Automotive Alliance	**Suitable for FABRIC**
Charging Infrastructure Operator. Load Balancing	FABRIC implementation assessment	**Suitable for FABRIC**
Infrastructure Charging Control	ISO/IEC 15118	**Suitable for FABRIC**
	UNPLUGGED	**Suitable for FABRIC**
Charging Assistance	Magnetic	**N/A**
	Vision based	**N/A**
	DGPS based	**N/A**
Payment	Smart or Credit Card	**Highly suitable for FABRIC (especially for static scenarios)**
	Mobile	**Suitable for FABRIC**

Technology group	Technology	Overall assessment
	ETC	**Highly suitable for FABRIC**
Road Operator Modules/Interface	TRIDENT	**Not suitable for FABRIC**
	RADEF	**Not suitable for FABRIC**
	TRANSMODEL	**Not suitable for FABRIC**
	DATEX II	**Highly suitable for FABRIC**
DSO communication technologies	GSM/GPRS	**Suitable for FABRIC**
	M-Bus	**Suitable for FABRIC**
	WM-Bus	**Highly suitable for FABRIC**
DSO ICT technologies	Web Services	**Highly suitable for FABRIC**
	ICCP	**Suitable for FABRIC**
	IEC 61850	**Suitable for FABRIC**

1. INTRODUCTION

1.1 General

The main purpose of this document is to assess several technologies that could be used for the implementation of the FABRIC system. The target audience is mainly the same FABRIC partners responsible for the implementation of this system, as they should take this document as an input for the definition of the implementation roadmap.

With this objective in mind, the next steps have been followed: first of all, a methodology has been proposed in order to build a homogenous analysis and assessment of the technologies under study. An important aspect of this methodology is the specification of a set of assessment criteria that will be evaluated against each proposed technology.

At the same time, several technology categories have been defined for each functional component included in the high level architecture of FABRIC platform. Then, inside each category, it has been proposed, reviewed and analysed several existing alternative technologies, from commercial sources, state of the art, internal developments of the FABRIC partners or other related initiatives. The main conclusions of this assessment has been the evaluation of the technologies against the assessment criteria previously proposed by the methodology

1.2 Contribution to FABRIC objectives

This document evaluates from a technical point of view the feasibility and easiness of adaptation, implementation, and integration of existing EV charging solutions and relevant ICT tools. This analysis considers several ICT and charging solutions, including communications and energy delivery, and evaluates the easiness of technological integration, including issues like size, required operational conditions, EMC, interfacing needs. It addresses all phases along the life cycle, including initial installation and maintenance.

The result is a report on the technical feasibility of various ICT and charging solutions, prioritized according to easiness of adaptation/implementation, technical integration and use. This guide should ease the latter development of the different components of the architecture, as it analyses and ranks several existing, applicable technologies for each of them.

1.3 Deliverable structure

- Chapter 1 is an introductory chapter that specifies the objective of the document, target audience and structure of the analysis.
- Chapter 2 specifies the methodology that has been used during the preparation of the report to obtain a homogeneous assessment of each of the technologies reviewed.
- Chapter 3 evaluates and assesses several charging solutions

- Chapter 4, similarly, reviews several ICT solutions that could be used in the implementation of the different functional components already defined in the preliminary conceptual architecture proposed for FABRIC.
- Finally Chapter 5 summarizes the analysis performed for each candidate technology and solution, ranking them to facilitate the posterior selection for implementation.

2. METHODOLOGY

The methodology followed for the technical feasibility study involved four main steps – namely "general" analysis, "FABRIC-oriented" analysis, gap and challenge analysis, and assessment and prioritization – as described in the following sections.

The overall approach is to obtain a quick scan of the different technologies, enabling all the solutions to be looked at once, discriminating those that are considered as unsuitable from the beginning; the remaining will be further investigated in the project, as additional requirements and restrictions appear.

2.1 General analysis

The first step considers whether the technology, techniques, resources (e.g. financial, technological, human), and skills do exist for the considered solution to be achieved. This preliminary step is necessary in order to have the big picture of the field, without missing important technologies that could at least be considered and compared as references. The analysis considers such questions as the following:

- What is being proposed: give details on the proposed solution and why it is being considered.
- How will it be implemented: do the technology and techniques needed for implementing the solution exist? Have they been used before on a project of this type? Have they ever been used before for any project?
- Technical capacity/ skills required: where has this solution been implemented before? What skills and experience are required?
- Human and financial resources: what are the identified costs and how might costs (technology, people, processes) change during the development of the solution? (high-level analysis).
- Constraints: what are the potential implementation challenges? What is the timeframe proposed and is it realistic? What are the potential gaps or challenges with the proposed approach?

2.2 FABRIC-oriented analysis

After evaluating whether the solution is feasible 'in principle,' developers must closely review the feasibility of the solution in the FABRIC actual context and with actual constraints. The following questions help in the analysis:

- Existing studies: what studies have been carried out so far to support this solution and proposed method? What further studies may be required either to ensure feasibility or meet statutory requirements? (Input from technical benchmarking of WP 2.3 regarding ICT solutions and WP 3.3 regarding on-road charging solutions)

- Technical capacity/skills: are the required skills and experience available or is external assistance needed? Are there external organizations or consultancies that might meet these needs?
- Financial resources: what is the expected budget and timeframe for the implementation of the solution, and are these realistic? Are implementation and measurable results expected within the time horizons?
- Constraints: what institutional support or approval is required? (Government sign-off, standards or codes, etc.) When and how can this be achieved? Are statutory approvals or environmental impact assessments required before implementation?
- Integration: what else is being developed in the project that might help or hinder the implementation of this solution?

2.3 Gaps and challenge analysis

The third stage of the technical feasibility methodology seeks to address any gaps or specific challenges that steps 1 and 2 might have identified. These are the key questions in this regard:

- What areas of the solution have been identified as challenging? What areas require further thought, planning, resourcing or technical assistance?
- Can these solution 'challenges' be addressed internally or is external assistance needed? Are further studies required to resolve challenges? Should a narrower or wider scope be considered? Should alternative or additional skills, capacities or techniques be considered?
- Would 'expert review' be helpful in any aspect of the proposed solution?
- Is the solution the best it can be (for the time, resources and budget?) How can it be improved?

2.4 Assessment

The final step of the feasibility analysis consists in the assessment and prioritization of the various solutions. This step evaluates the solutions emerged from the previous three stages on the basis of a set of assessment criteria such as the following (Section 2.4.1 and 2.4.2).

The final evaluation step will consist, for each one of the investigated solutions, in a justified overall assessment with a final synthetic score on a 3-point scale: Highly suitable for FABRIC, Suitable for FABRIC, Not suitable for FABRIC. These scores reflect the expert consensus of the involved partners.

It is important to highlight that the assessment is focused on the current implementation of the different components of the system in the current scope of FABRIC project, in order to produce a highly usable report. However, in other activities of the project, a broader scope has been

applied, taking into consideration a distant horizon in order to define the strategic roadmap for the future systems beyond FABRIC.

2.4.1 Assessment criteria for charging solutions:

- Performance of the solution (low, medium or high)
- EMC issue (low disturbances or high disturbances)
- Closeness to market (low effort or high effort)
- Cost (low, medium or high)
- Maturity (low, medium or high)
- Safety (not safe, enough safe or very safe)
- Scalability in terms of vehicles and road coverage (not scalable or scalable)

2.4.2 Assessment criteria for ICT solutions

- Implementation of the solution (easy, medium or difficult)
- Interoperability between different car makers (easy, medium or difficult)
- Cost of the ICT tools (low, medium or high)
- Security (low, medium or high)
- Safety (low, medium or high)
- Efficiency (low, medium or high)
- Maintenance (easy, medium or difficult)
- Usability (easy, medium or difficult)
- Closeness to market (low effort to market or high effort to market)

3. ASSESSMENT OF CHARGING SOLUTIONS

3.1 Introduction

The objective of this section is to apply the methodology defined in Task 4.2.1 to evaluate the feasibility of the different charging solutions described in SP3. The different solutions are briefly reminded.

The study describing the different charging solution has been done in SP3, in Task 3.3.1 Review of existing charging solutions. Therefore, in this document we present only a summary of the different solutions. For deep details see document D33.1 Review of existing solutions [1] as is considered an input for the current report. The evaluation is based on the features provided in SP3.

The criteria used in the following tables can be developed as follow:

- Performance of the criteria: this concerns the performance in terms of electrical efficiency of the system (power electronics + electromagnetic coupling device)
- EMC issue: It is the EMC behaviour of the system (when it has been measured). It considers conducting disturbances (emission and susceptibility) and radiated disturbances (emission and susceptibility).
- Closeness to market: This criterion measures how easy it will be to put the technology on the market.
- The cost
- Safety: it is understood as electrical safety.
- Scalability: It measures how easy it will be to deploy the technology by increasing or decreasing its power to cover roads.

In this section a value will be given according to the assessment criteria defined in chapter 2.4.2. In addition we include a “N/A” value. This value is allotted for the criteria which are not available in SP3 study or criteria which were not measured or quantified.

3.2 POLITO CWD WPT solution

The solution is based on dynamic wireless resonant inductive coupling principle. The system is currently in development and is particularly adapted to FABRIC Project. The efficiency of the overall system is greater than 75% (this comprises the power electronics module and the electromagnetic coupler). With an air gap of 20cm, this efficiency can be classified between the highest. As it is inductive, the output of the system is electrically isolated from the grid. We have a high level of electrical safety.

The system is still under development. In terms of scalability, as the power rate is 20kW, to meet the FABRIC requirements in terms of power, several converters must be connected in parallel on the grid side. The system will have a DC voltage distribution and the coils+

resonance capacitor will be individually supplied. Then, the power rate of the inductive part should also be increased, which needs a redesign of the inductor. For these reasons, we consider medium scalability.

Table 3: Assessment table for POLITO CWD WPT solution

	Assessment grade
Performance of the solution	High
EMC issue	N/A
Closeness to market	Medium
Cost	N/A
Maturity	Medium
Safety	Enough safe
Maintenance	N/A
Scalability in terms of vehicles and road coverage	Scalable
Overall assessment	**Suitable for FABRIC**

3.3 SAET Spa- Induction powered vehicle (IPV)

IPV solution is based on wireless resonant inductive power transfer. It is a system for on road charging vehicles. The specifications indicate an operational speed of 80km/h and the power rate is 100kW. The efficiency of the overall system is between 70 and 80% with an air-gap of 25cm. There are no EMC values available.

Table 4: Assessment table for IPV

	Assessment grade
Performance of the solution	Medium
EMC issue	N/A
Closeness to market	High effort
Cost	N/A
Maturity	Low

Safety	Enough safe
Maintenance	Medium
Scalability in terms of vehicles and road coverage	Scalable
Overall assessment	**Suitable for FABRIC**

3.4 KAIST - Online Electric Vehicle (OLEV)

It is one of the first wireless dynamic charging solutions developed. It is one of the first dynamic charging systems developed. OLEV buses are currently in operation in Seoul. Note that the vehicle also charge statically en-route in the bus stops. The efficiency of the system is 75% in dynamic functioning with an air gap of 27cm. The system complies with ICNIRP 2010 in terms of EMC behaviour. Therefore, the system has a high level of maturity.

The single power electronic has a rate of 20kW and the system has a power rate up to 200kW (20kW/pickup and 5 pickups per bus).

Table 5: Assessment table for OLEV

	Assessment grade
Performance of the solution	High
EMC issue	Low disturbances
Closeness to market	Low effort
Cost	N/A
Maturity	High
Safety	Enough safe
Maintenance	Medium
Scalability in terms of vehicles and road coverage	Scalable
Overall assessment	**Highly suitable for FABRIC**

3.5 Conductix Wampfler IPT

IPT is Conductix Inductive Power Transfer system. It is wireless resonant inductive power transfer system. This system is used in opportunistic charging. It is stationary charging which

occurs for short time. The system is currently used in Genoa. It means that some efforts are needed to make it work for on road charging. The efficiency is 93% for 4 cm height for the air gap. Note that the efficiency is high but the air gap is very low. For an on road charging system, this air gap is too small. So to adapt it to FABRIC project, this value should be increased. This will decrease the efficiency.

The system has met radiated, conducted and immunity standard and also ICNRP 2010 standard.

Table 6: Assessment table for Conductix Wampfler IPT

	Assessment grade
Performance of the solution	High
EMC issue	Low disturbances
Closeness to market	Low effort
Cost	N/A
Maturity	High
Safety	High safety
Maintenance	Medium
Scalability in terms of vehicles and road coverage	Scalable
Overall assessment	**Suitable for FABRIC**

3.6 Plugless Power

This solution is static resonant inductive charging solution. It is commercial solution developed by Evatran in partnership with Bosch. It is currently offered to the Chevrolet Volt and Nissan Leaf customer only. It has 3.3kW power rate and is a static charging solution. The efficiency is 87% with an air gap of 10cm. It is a single unit connected to the mains. For static charging in FABRIC it is Suitable but efforts are needed to meet dynamic charging, specifically the scalability.

Table 7: Assessment table for Plugless Power

	Assessment grade
Performance of the solution	High

EMC issue	N/A
Closeness to market	Low effort
Cost	Low
Maturity	High
Safety	High safety
Maintenance	Medium
Scalability in terms of vehicles and road coverage	Scalable
Overall assessment	**Suitable for FABRIC**

3.7 Witricity

The company was formed to commercialise the wireless power transfer system developed in MIT. This system has been provided to numerous OEMs and vehicle manufacturers.

The power rate of this system is from 300W to 3.3kW. The efficiency is 90% with an air gap of 18cm and misalignment of 20cm. Thus the performance of the system is considered high. This solution is used in static mode charging. To cover the dynamic charging as in FABRIC Project, the system unit can be split and also paralleled to increase power rate.

Electrical safety is ensured due to inductive solution. There is no contact on secondary side with the grid side.

Table 8: Assessment table for Witricity

	Assessment grade
Performance of the solution	High
EMC issue	N/A
Closeness to market	Low effort
Cost	N/A
Maturity	High (TRL level 8)
Safety	Enough safe

Maintenance	Medium
Scalability in terms of vehicles and road coverage	Scalable
Overall assessment	**Suitable for FABRIC**

3.8 Siemens eHighway

System similar to rail electrification, the power is transferred from overhead cables to the vehicle's on board traction or battery. So it is conducted solution. Such system has demonstrated its feasibility in overhead systems like for buses. To adapt such system to FABRIC project, we need big effort and it is not flexible in terms of road infrastructure.

Table 9: Assessment table for Siemens eHighway

	Assessment grade
Performance of the solution	High
EMC issue	N/A
Closeness to market	Medium effort
Cost	High
Maturity	High
Safety	Enough safe
Maintenance	Low
Scalability in terms of vehicles and road coverage	Low
Overall assessment	**Not suitable for FABRIC**

4. ASSESSMENT FOR ICT SOLUTIONS

4.1 Preliminary Functional Architecture

In this section, the potential technologies that could be used for the implementation of the FABRIC ICT platform are reviewed and assessment.

With this objective, the high level architecture of the overall FABRIC system has been used as a guideline for the selection of supporting ICT technologies that could totally or partially support the expectations defined for each of the functional components described in the architecture.

This initial high level architecture has been proposed as part of the activities of task T4.3.1 Use case definition to produce official deliverable D43.1 FABRIC Final use cases [2].

Following, the overview diagrams of this functional architecture are included, for the OBU description as well as off-board modules

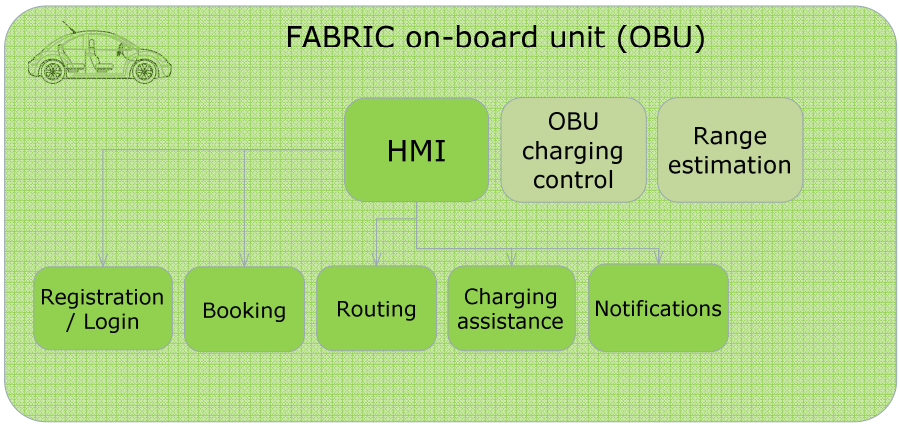

Figure 1: FABRIC OBU preliminary functional architecture

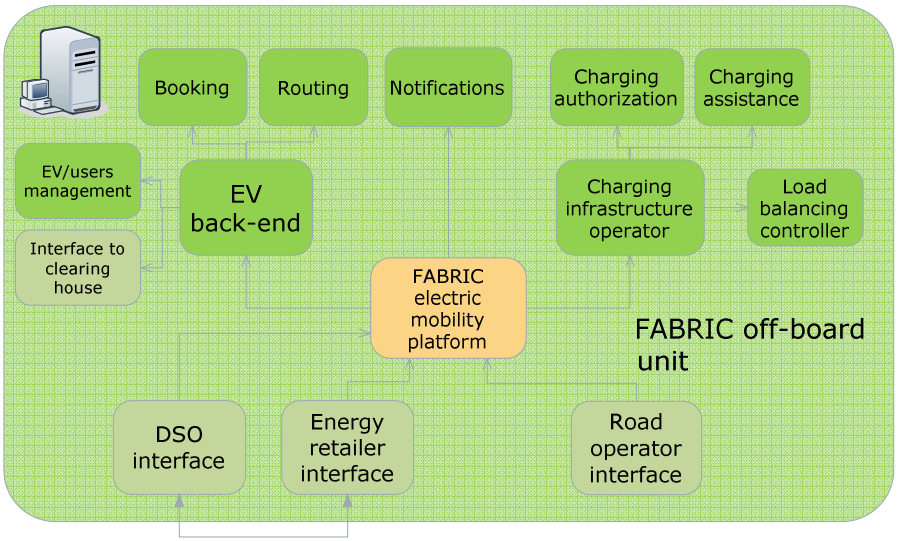

Figure 2: FABRIC off-board unit preliminary functional architecture

Using this architecture, the following technology categories have been defined:

- FABRIC Electric Mobility Platform: it will function as the brain of the system and it will coordinate the actions of all peripheral modules by processing, filtering and routing the communications and information flow. All information coming from the external actors of the system pass through this module and are processed in order to present the driver with notifications that are coherent and discrete enough so as to not distract from driving. With the cooperation of the EV back-end it validates booking operations taking into account grid and road status.
- Identification technologies: a basic requirement that will support any other functionality is the right authentication and authorization of the vehicle/user that access the charging infrastructure.
- Routing: it will provide navigation functionalities as current navigation systems but with extended functionalities and features to facilitate EV charging.
- Connected car and HMI: it refers to the interaction with the final user (driver) as well as the support of local apps and high-level connectivity. It should support the handling of booking and routing operations mirroring and working in tandem with the corresponding functionalities of the FABRIC OBU, implemented using the HMI that gives access to the user to many of these functionalities.
- Charging Infrastructure Operator and Load Balancing Control: it is an internal actor and controls the actual charging of the EVs and will be physically installed close to the infrastructure or integrated in it. It provides charging authorization and charging assistance functionalities but also handles the low-level balancing of the load among the many EVs that will be charging at the same time.
- Infrastructure Charging Control.
- Charging assistance: once the drivers are close to the charging facility, the HMI will guide them through the whole process.
- Payment Interfaces, to allow the billing functionalities.
- Road Operator interface: it provides an access point to FABRIC so that the charging and road infrastructure availability status can be updated in order to notify drivers for scheduled or unscheduled events that may affect their charging scheduling. The road operator also has the ability to control directly the infrastructure in cases of emergency.
- DSO and retailer modules and interfaces.

In the next sections, several candidate ICT solutions are reviewed and assessed for each category, trying to define the important aspects that should be taking into account for the implementation of them.

Please, refer to [2] for a detailed description of the specification of these functional components and modules.

4.2 FABRIC Electric mobility platform

In the next section, the potential supporting technologies for the FABRIC Electric mobility platform are analysed.

As previously described, this core module will function as the brain of the system and it will coordinate the actions of all peripheral modules in Fig 2 by processing, filtering and routing the communications and information flow. So, this is a fundamental and complex part of the architecture.

For this reason, two different approaches have been taken for the analysis of the module: on the one hand, it has been considered the implementation using different basic technologies that each of them could partially answer some of the expectations of the module; then, once combined, it could bring the overall capabilities.

On the other hand, other related platforms and initiatives that focus on similar functionalities have been considered and analysed in order to reuse existing technical approaches.

4.2.1 Baseline technologies

The objective of this section is to describe and evaluate the different solutions that can support a direct implementation of the electric mobility platform.

The identified functionalities of the platform are:

- It interfaces with the external actors (DSO, Energy retailer, Road operator)
- It interfaces with the internal actors (Charging infrastructure operator, EV backend operator)
- It coordinates actions inter-modules and collects information of vehicles, grid operators and road operators taking real-time decisions about the service.
- It validates the charging booking operations taking into account grid and road status.
- It can send notifications to drivers, grid operators, road operator specifying changes in routing, bookings, incidents, etc.

These solutions should provide the following capabilities:

- Service Bus: For managing messages and events and routing them to the appropriate destination.
- Process Management & Service orchestration: For define booking, billing, user management processes as well to coordinate the invocation of the different operator's interfaces).
- Complex event processor: For analysis of the events flow generated by the different FABRIC modules and configures the generation of alerts.

In this section, the main current solutions as well as their advantages and disadvantages are described.

The FABRIC electric mobility platform requires assembling different ITC solutions as well as custom software developments.

The survey of ICT solutions that can support the implementation of the Electric Mobility platform are therefore classified by the previously identified ICT functionalities:

- Service Bus
  - Open ESB
  - WSO2 ESB
  - ServiceMix
- Business processes and Service orchestration
  - WSO2 Business Process Server
  - Apache ODE
- Complex event processor (analysis of events and generation of alerts
  - WSO2 CEP
  - Esper

4.2.1.1 Service Bus

4.2.1.1.1 WSO2 ESB

WSO2 Enterprise Service Bus provides a highest performance, lowest footprint, and most interoperable SOA and integration middleware, delivering a smooth start-to-finish project experience. It is highly efficient with a lean footprint due to the variety of standards supported. For example, a deployed WSO2 ESB often fits within a 160 MB memory space. For example, eBay infrastructure uses WSO2 Enterprise Service Bus to process over 1 billion transactions per day.

Features

- Connecting Anything to Anything
  - Transports: HTTP, HTTPS, POP, IMAP, SMTP, JMS, AMQP, FIX, TCP, UDP, FTPS, SFTP, CIFS, MLLP, SMS
  - Formats & protocols: JSON, XML, SOAP 1.1, SOAP 1.2, WS-*, HTML, EDI, HL7, OAGIS, Hessian, Text, JPEG, MP4, All binary formats, CORBA/IIOP
  - Adapters to COTS systems: SAP BAPI & IDoc, PeopleSoft, MS Navision, IBM WebSphere MQ, Oracle AQ, MSMQ
  - Adapters to cloud services: Salesforce, Paypal, LinkedIn, Twitter, JIRA
- Routing, Mediation & Transformation
  - Routing: Header based, content based, rule-based and priority-based routing

    - Mediation: EIPs (including scatter/gather, message filters, recipient list, dead-letter channels, guaranteed delivery and message enrichment), database integration, event publishing, logging & auditing, validation
    - Transformation: XSLT 1.0/2.0, XPath, XQuery, Smooks
- Message, Service, API & Security Gateway
    - Expose existing applications & services over different protocols & message formats
    - Virtualize services for loose coupling & SOA governance
    - Load balancing for scalability and fail-over for high availability of business endpoints
    - Create service facades for legacy / non-standard services
    - Enforce and manage security centrally, including authentication, authorization & entitlement
    - Policy enforcement and governance via WSO2 Governance Registry
    - Expose services & applications via RESTful APIs with key management
    - Logging, audit and SLA monitoring, KPI monitoring
    - WS-Security, LDAP, Kerberos, OpenID, SAML, XACML
    - SSL tunnelling and SSL profiles support for inbound and outbound scenarios
    - CRL/OCSP Certificate revocation verification
- High Performance, High Availability, Scalability & Stability
    - Supports 1000s of concurrent non-blocking HTTP(S) connections per server
    - Pure streaming and on-demand processing of messages
    - Sub-millisecond latency for high-throughput scenarios
    - Supports highly available deployment
    - Horizontal scaling via clustering with stateless server architecture
    - Long term execution stability with low resource utilization
- Lightweight, Developer Friendly and Easy to Deploy
    - Declarative development with configuration instead of code
    - Easy configuration of fault tolerant mediations with support for error handling
    - Server customization via feature provisioning of any WSO2 middleware capability
    - Choice of deployment to on-premise servers, private cloud or public cloud (WSO2 Enterprise Service Bus-as-a-Service) without configuration changes
    - Extend configuration language with custom DSLs via templates
    - Embed scripting language code in Javascript, JRuby, Groovy and more as custom mediators
    - Integrated with SVN, Maven, Ant and other standard tools for development & deployment
    - Integrated to WSO2 Developer Studio, Eclipse-based IDE for all WSO2 products.

- Manage & Monitor
    - Comprehensive management & monitoring Web console with enterprise-level security
    - Built-in collection and monitoring of standard access and performance statistics
    - JMX MBeans for key metrics monitoring and management
    - Integrates with WSO2 Business Activity Monitor for operational audit and KPI monitoring and management
    - Flexible logging support with integration to enterprise logging systems
    - Centralized configuration management across different environments with lifecycles and versioning via integration to WSO2 Governance Registry

Assessment of the technology

Implementation of the solution: Easy

Development graphic console with wide documentation.

Interoperability between different solution providers: Easy

Use of standard formats and protocols.

Cost of the ICT tool: Low

Open Source

Security:High

Full security standards coverage (WS-*, SAML, OpenId) and advanced utilities like Certificate revocation verification

Safety: N/A

Efficiency: High

- Supports 1000s of concurrent non-blocking HTTP(S) connections
- Pure streaming and on-demand processing of messages
- Sub-millisecond latency for high-throughput scenarios
- Horizontal scaling via clustering with stateless server architecture
- Long term execution stability with low resource utilization

Maintenance: Easy

Graphic consoles for development, monitor and management.

Usability: N/A

Closeness to market: Low effort

The platform is already on the market and applications have been tested in several projects.

4.2.1.1.2 Open ESB

Developed by the OpenESB community, it is an efficient ESB tool for building Integration and SOA applications.

Initially designed and developed by Sun Microsystems, OpenESB provides the ability to create composite service-oriented applications once and deploy them anywhere on any application server or stand-alone java environment, and on any operating system and hardware platform or virtual or cloud environments.

It is not a cloud solution but its architecture matches perfectly with new cloud architectures and allows easy deployment and management on very complex infrastructures.

OpenESB consists of a runtime, a design time, and a management console. The runtime consists of a light-weight JBI core, and several components. There is also support for other application servers and it also can be run as a stand-alone application.

The design time consists of a number of plugins that can be installed in the NetBeans IDE. Design time plugins include an extensive BPEL editor, XSLT editor, XSD editor, WSDL editor, and facilities for data mapping. There is minimal support for Eclipse, but there are plans to improve this.

Features

- Messaging
  - Support for SOAP, REST, JMS, HTTP, FTP, File, Database, LDAP.
  - Composition/Orchestration/Transformation
  - Support for BPEL, JBI, XSLT.
- Security
  - Basic Authentication/Authorization: Sun Java Access Manager WssToken Compare, Glassfish security realm.
  - Brokered Authentication: Use of a authentication Broker, WSIT, X509 Security token, SAML, WS-Security
  - Encryption/Decryption.
- License
  - Open Source

Assessment of the technology

Implementation of the solution: Medium

Development graphic design plugins.

Interoperability between different solution providers: Easy

Use of standard formats and protocols.

Cost of the ICT tool: Low

Open Source

Security:Medium

Security standards coverage (WS-*, SAML)

Safety: N/A

Efficiency: High

Cloud-oriented deployment provides high scalability and performance

Maintenance: Medium

Management console and Graphic development plugins for IDEs.

Usability: N/A

Closeness to market: Low effort

The platform is already on the market and applications have been tested in several projects..

4.2.1.1.3 ServiceMix

Apache ServiceMix is an enterprise-class open-source distributed enterprise service bus (ESB) based on the service-oriented architecture (SOA) model.

ServiceMix 4 fully supports the OSGi framework. ServiceMix is lightweight and easily embeddable, has integrated Spring Framework support and

can be run at the edge of the network (inside a client or server), as a standalone ESB provider or as a service within another ESB.

It is the JBI implementation of the Apache Software Foundation. For the carriage of messages on the bus Java Messaging Service in short JMS is used. The used implementation of JMS is Apache ActiveMQ. Every time a message of a component is sent through ServiceMix's Bus it is transmitted through the JMS infrastructure. The message queues which have been created especially for this can be monitored with a Java Management Extensions JMX Console. By

using JMS for message exchange the bus is getting its Quality of Service characteristics as: message persistence or support of transactions.

Therefore ServiceMix can continue doing its work where it has been interrupted. ServiceMix uses the Apache XBean project for configuration. XBean features an in-depth integration of the Spring Framework. The whole configuration is done by the Spring XML format. Even Service Units are configured with XBeans. Some components also offer the possibility to exchange some components by using XBeans. For example you can engage a file filter implemented in java into the File Component. Therewith Java can be used in this ServiceMix Component. This offers a lot more possibilities than a "common" configuration.

Tool Support

ServiceMix is a typical Apache project which can be administrated by command line or Maven2. Plugins for Maven2 are also the only ones bundled with ServiceMix. Those who aren't familiar with Maven2 will need some time for familiarization. Afterwards you can manage your service assemblies and their dependencies to service units very comfortable with Maven2. There is also no need for an administration tool for components and service assemblies, because the desired activities can be done quickly by deleting or copying files.

Components

The ServiceMix distribution already contains numerous binding components and service engines. Following connectors are provided:

- File
- FTP
- HTTP
- JMS
- Mail
- SOAP
- Service Engines are available amongst others for:

Name	Description
Bean	Java POJOs (Simple Java Class)
Drools	Router or Services can be realised with rules of the Drools Rule Engine
EiP	EiP Enterprise Integration Patterns taken from the book of Hohpe und Woolf e.g. filter, splitter, content-based router, pipeline, content enricher
Quartz	Scheduler

Saxon	XSLT engine for transformations

- Scripting Services can be created with nearly any scripting language as Ruby, Perl or Groovy. Linked by JSR-223 Scripting for the Java Platform
- ValidationSchema validation with XML schema or Relax NG (ServiceMix 3.3 or newer)

ServiceMix is distributed with more components as the OpenESB Netbeans or Glassfish distribution. Altogether there are more Components available for the OpenESB as for ServiceMix. The JBI specification promises the exchangeability of integration components between the several ESB: In Practise this doesn't work smoothly, but it surely will change in future.

Orchestration and Routing

Contrary to OpenESB BPEL is not needed for orchestration and routing. The ServiceMix distribution doesn't even contain a BPEL engine. If BPEL support is desired for ServiceMix, a BPEL engine like Apache ODE can be installed as JBI component.

There are several alternatives for routing in ServiceMix. The simplest solution is the Enterprise Integration Patterns service engine. It offers besides others an XPath splitter, an aggregator, a routingslip and a content based router. A more powerful option is the Camel SE. Apache Camel is an open source integration framework. Routing rules can be created using a Java based Domain Specific Language (DSL) or using a Spring configuration. Besides this, ServiceMix offers a SE for the Drools Business Rule Management System. And of course you can use BPEL.

Runtime Environment

ServiceMix is modest in resource consumption. During development ServiceMix can be ran immediately in a Java VM without an application server. It's even possible to run ServiceMix out of a JUnit Test or to run ServiceMix embedded in other applications. An integration of ServiceMix into Geronimo, JBoss, Tomcat or other servers is also possible.

Performance

ServiceMix can also process more than 10000 messages per minute. The performance doesn't suffer considerably even when the messages are persisted by ActiveMQ and Apache Derby data base. If the performance doesn't suffice, for example due to complex XSLT Transformations, ServiceMix can be clustered. Therefore ServiceMix and the service assembly has to be installed on several computers. Using mulitcast they find each other and distribute the load across multiple computers.

Assessment of the technology

Implementation of the solution: Difficult

File-based development

Interoperability between different solution providers: Easy

Use of standard formats and protocols.

Cost of the ICT tool: Low

Open Source

Security:Medium

Basic security standards (WS-security, JAAS)

Safety: N/A

Efficiency: Medium

More than 10000 messages per minute, clustering and multicast

Maintenance: Low

File based development, basic management console.

Usability: N/A

Closeness to market: Low effort

The platform is already on the market and applications have been tested in several projects.

4.2.1.2 Process Management & Service Orchestration

4.2.1.2.1 Apache ODE

Apache ODE (Orchestration Director Engine) software executes business processes written following the WS-BPEL standard. It talks to web services, sending and receiving messages, handling data manipulation and error recovery as described by your process definition. It supports both long and short living process executions to orchestrate all the services that are part of your application.

WS-BPEL (Business Process Execution Language) is an XML-based language defining several constructs to write business processes. It defines a set of basic control structures like conditions or loops as well as elements to invoke web services and receive messages from services. It relies on WSDL to express web services interfaces. Message structures can be manipulated, assigning parts or the whole of them to variables that can in turn be used to send other messages. More about the specification can be found on our BPEL page.

Features

- Side-by-side support for both the WS-BPEL 2.0 OASIS standard and the legacy BPEL4WS 1.1 vendor specification.
- Supports 2 communication layers: one based on Axis2 (Web Services http transport) and another one based on the JBI standard (using ServiceMix).
- Support for the HTTP WSDL binding, allowing invocation of REST-style web services.
- Possibility to map process variables externally to a database table of your choice.
- High level API to the engine that allows you to integrate the core with virtually any communication layer.
- Hot-deployment of your processes.
- Compiled approach to BPEL that provides detailed analysis and validation at the command line or at deployment.
- Management interface for processes, instances and messages.

Assessment of the technology

Implementation of the solution: Medium

XML-based development and limited documentation.

Interoperability between different solution providers: Easy

Use of standard languages (WS-BPEL) and protocols (REST)

Cost of the ICT tool: Low

Open Source

Security: Medium

Basic security

Safety: N/A

Efficiency: Medium

In memory processing

Maintenance: Medium

XML based development, management interface.

Usability: N/A

Closeness to market: Low effort

The platform is already on the market and applications have been tested in several projects.

4.2.1.2.2 WSO2 Business Process Server

Business Process Management is a key technology for increasing productivity and re-energizing businesses, making them more competitive. The WSO2 Business Process Server enables developers to easily deploy business processes written using the WS-BPEL standard, and also serves as the business process management and hosting environment for your SOA.

Powered by the Apache Orchestration Director Engine (ODE) BPEL engine, the WSO2 Business Process Server provides a complete web-based graphical console to deploy, manage and view processes.

Features

- Define and Execute Business Processes
  - Supports WS-BPEL 2.0 and BPEL4WS 1.1
  - Long running stateful processes
  - Short running stateless or stateful processes
  - In memory process execution for short running processes
  - Message and time triggered message handling
  - Processes secured with WS-Security, Kerberos and more
  - Security context propagation through processes to partners
  - Secure invocation of partners with WS-Security, Kerberos and more
- Data Manipulation & Extensibility
  - Powerful data manipulation via XPath 1.0/2.0, XSLT 1.0/2.0, XQuery 1.0 and E4X
  - Extensible via custom activities defined using Java APIs
  - XPath extensions for Java invocation
- Define Workflows Interacting with People
  - Supports WS-Human Task 1.1, BPEL4People 1.1
  - Integration of people for performing tasks and receiving notifications
  - Management of deadlines and escalation to other users and roles (including integration to WSO2 Identity Server for user and role management)
  - Role based access control for activities
  - Google Gadget for interacting with task manager and for task execution
  - Ability to create custom user interfaces for tasks
- Create & Monitor Custom Key Performance Indicators (KPIs)
  - Extension activity for selectively publishing events from any process to WSO2 Business Activity Monitor

    - Define KPIs to run in WSO2 Business Activity Monitor and generate custom gadgets for dashboards or reports
- Graphical Process Modeling
    - Powerful graphical editor via WSO2 Developer Studio
    - Drag-n-drop visual editor for any WS-BPEL process model including XPath assistant
    - Store, lifecycle manage and govern processes, partners and endpoints via integration with WSO2 Governance Registry
    - Create and manage process deployment artifacts
    - Import and edit BPEL processes developed using other tools such as SoftwareAG ARIS, Oracle SOA Suite, Microsoft BizTalk and IBM Process Manager
- Process Management via Graphical Administration Console
    - Flexible deployment and management of processes including security, throttling and caching
    - Process versioning including dynamic updates to running processes
    - Flexible management of process instances including terminate, suspend, resume, retry and cleanup
    - Graphical auditing and troubleshooting of instances
    - Dashboard with snapshot of failed, suspended, active and long running instances

Assessment of the technology

Implementation of the solution: Easy

Development studio and wide documentation.

Interoperability between different solution providers: Easy

Use of standard languages (WS-BPEL)

Cost of the ICT tool: Low

Open Source

Security: High

Support of security standards (Ws-security, Kerberos)

Safety: N/A

Efficiency: High

Long and short processes support. In memory processing

Maintenance: High

Development studio, Graphical administration console with flexible management.

Usability: N/A

Closeness to market: Low effort

The platform is already on the market and applications have been tested in several projects..

4.2.1.3 Complex Event processing

4.2.1.3.1 WSO2 Complex Event Processing

Routine business operations (a flight landed, a credit card processed, a package shipped) generate a constant stream of events. In a fast changing and competitive business climate, enterprises that monitor complex sequences of real-time events can quickly respond to their environment by anticipating problems and flagging opportunities. This will have greater business advantage over their competitors.

WSO2 Complex Event Processor identifies the most meaningful events within the event cloud, analyses their impacts, and acts on them in real time. Built to be extremely high performing and massively scalable, it offers significant time saving and affordable acquisition.

Features

- Extremely High Performant Processing Engine
  - Processes more than 2.5M events/sec on single server commodity hardware.
  - Powered by WSO2 Siddhi.
- Powerful and Extensible Query Language for Temporal Event Stream Processing
  - Filter events by conditions.
  - Join event streams and create new streams.
  - Execute temporal queries using various windows.
  - Detect and respond to various event patterns and sequences.
  - Process historical data in RDBMS in real-time.
- Support for Rich Event Model
  - Events modeled as tuples of data, metadata and correlation data.
  - Support for typed properties including integral types, floating types, string and boolean.
- Extremely High Performant Event Capturing and Delivery Framework Over Apache Thrift or HTTP
  - Java data publisher agent to plug into any Java based system.
  - Data publisher agent support in other languages (C/C++/C#) via Thrift language bindings.

    - Horizontally scalable to support very large event volumes.
- Easily Integrates with any Enterprise System for Event Capture
    - RESTful HTTP protocol with JSON, XML and Text.
    - JMS Map, JSON, XML and Text messages.
    - SOAP over any transport protocol
    - Kafka, File and Email protocols with JSON, XML and Text messages
- Effective Event Publishing to Enterprise Systems and Custom Notifications
    - XML, JSON, Map, Text events via JMS protocol.
    - E-mail, SMS notifications.
    - Service calls to notify RESTful services and Web services.
    - MySQL and Cassandra writers.
- Debugging Support
    - Event tracing, flow visualization and event simulation capabilities..
- Massively Scalable
    - Supports large numbers of queries via partitioning into different servers.
    - Massive working memory support via distributed caching with Hazelcast.
    - Distributed chaining of complex queries.
- Highly Available Deployment
    - Run multiple CEPs configured with a Hazelcast distributed cache as a shared working memory.
- Support for Long Duration Queries.
    - Queries can span lifetimes much greater than server uptime.
    - Supports periodic snapshots that can store all state information and windows to a scalable persistence store (Apache Cassandra).
    - Pluggable persistent stores.
- Tightly Integrates with WSO2 Business Activity Monitor
    - Leverage Lambda architecture to integrate post-processed data with real-time data processing
    - Supports recording and post processing of events with Map-Reduce via Apache Hadoop.
- Lightweight, Developer Friendly and Easy to Deploy
    - Server customization via provisioning of features.
    - Deployment options from on-premise to private or public clouds, without configuration changes.
    - Integrated with WSO2 Developer Studio, the Eclipse-based IDE for all WSO2 products.
- Manage & Monitor

- Comprehensive management and monitoring Web console with enterprise-level security.
- Built-in collection and monitoring of standard access and performance statistics.
- Flexible logging support with integration to enterprise logging systems.
- In build support for rich representation of data through a dashboard

Assessment of the technology

Implementation of the solution: Easy

WSO2 Development studio, powerful query language and wide documentation.

Interoperability between different solution providers: Easy

Easily Integrates with any Enterprise System for Event Capture by using standard protocols:

- RESTful HTTP protocol with JSON, XML and Text.
- JMS Map, JSON, XML and Text messages.
- SOAP

Cost of the ICT tool: Low

Open Source

Security: Medium

Enterprise-level security

Safety: N/A

Efficiency: High

- Support for Long Duration Queries
- Massively scalable
- Extremely High Performant Event Capturing

Maintenance: High

Management and monitoring Web console and WSO2 Development studio.

Usability: N/A

Closeness to market: Low effort

The platform is already on the market and applications have been tested in several projects..

4.2.1.3.2 Esper

Esper is a component for complex event processing (CEP) and event series analysis, available for Java. Esper enables rapid development of applications that process large volumes of incoming messages or events, regardless of whether incoming messages are historical or real-time in nature. Esper and filter and analyse events in various ways, and respond to conditions of interest.

Esper and Event Processing Language (EPL) provide a highly scalable, memory-efficient, in-memory computing, SQL-standard, minimal latency, real-time streaming-capable Big Data processing engine for historical data, or medium to high-velocity data and high-variety data.

Esper Provides an Online Application for EPL Learning: Esper EPL Online

Technology Introduction

Complex event processing (CEP) delivers high-speed processing of many events across all the layers of an organization, identifying the most meaningful events within the event cloud, analysing their impact, and taking subsequent action in real time.

Esper offers a Domain Specific Language (DSL) for processing events. The Event Processing Language (EPL) is a declarative language for dealing with high frequency time-based event data. SQL streaming analytics is another commonly used term for this technology.

Some typical examples of applications are:

- Business process management and automation (process monitoring, BAM, reporting exceptions, operational intelligence)
- Finance (algorithmic trading, fraud detection, risk management)
- Network and application monitoring (intrusion detection, SLA monitoring)
- Sensor network applications (RFID reading, scheduling and control of fabrication lines, air traffic)

Feature Summary

- GUI for design and management of EPL statements and CEP engine in general (JavaScript and HTML 5)
- EPL editor and debugger; Detailed breakdown of memory use and metrics for all EPL statement state (data windows, indexes, aggregations etc. memory use)
- Real-time continuously-updating displays; jQuery plug-in, dashboard builder, JavaScript API
- REST Web Services for CEP engine and push management
- Full support for applications that embed Esper (does not require Enterprise Edition server)

- Hot deployment of EPL modules and event-driven applications
- Highly scalable, elastic, distributable and fault tolerant event processing
- Integration with common distributed caches

Assessment of the technology

Implementation of the solution: Medium-high

GUI for design and management of EPL statements and CEP engine

Interoperability between different solution providers: Medium

- REST Web Services for CEP engine and push management
- Full support for applications that embed Esper

Cost of the ICT tool: Low

Open Source

Security: Medium

Basic security in development and management GUI

Safety: N/A

Efficiency: Medium

Highly scalable, elastic, distributable and fault tolerant event processing

Maintenance: Medium

GUI for design and management of EPL statements and CEP engine

Usability: N/A

Closeness to market: Low effort

The platform is already on the market and applications have been tested in several projects.

4.2.2 IBM Platform: IOC – Intelligent Operations Center

While in section 4.2.1, the selected approach has been the use of baseline technologies for the implementation of the FABRIC Electric Mobility Platform, in this section the focus is set in finding complete platforms already implemented or under construction that could be adapted to the expected functionalities of the EMP. As this is a quite focused application, only one of the potential applicable technologies initially considered have been included in the assessment as the available information and/or suitability for FABRIC of other possibilities seemed far beyond the IBM option.

IBM developed a platform for smart city applications. Typical functionalities such as Data acquisition (Data integration broker), analytics and visualization are foreseen. The data integration broker can contain the different FABRIC interface modules in order to communicate with the actors (charging station, DSO, Retailer, etc.). Figure 3: Example of a component model of the IOC

shows an example of a component model. More details on the product can be found in the IBM Redbook “IBM Intelligent Operations Center 1.6 Programming Guide”, which is available on the internet (http://www.redbooks.ibm.com/abstracts/sg248201.html?Open).

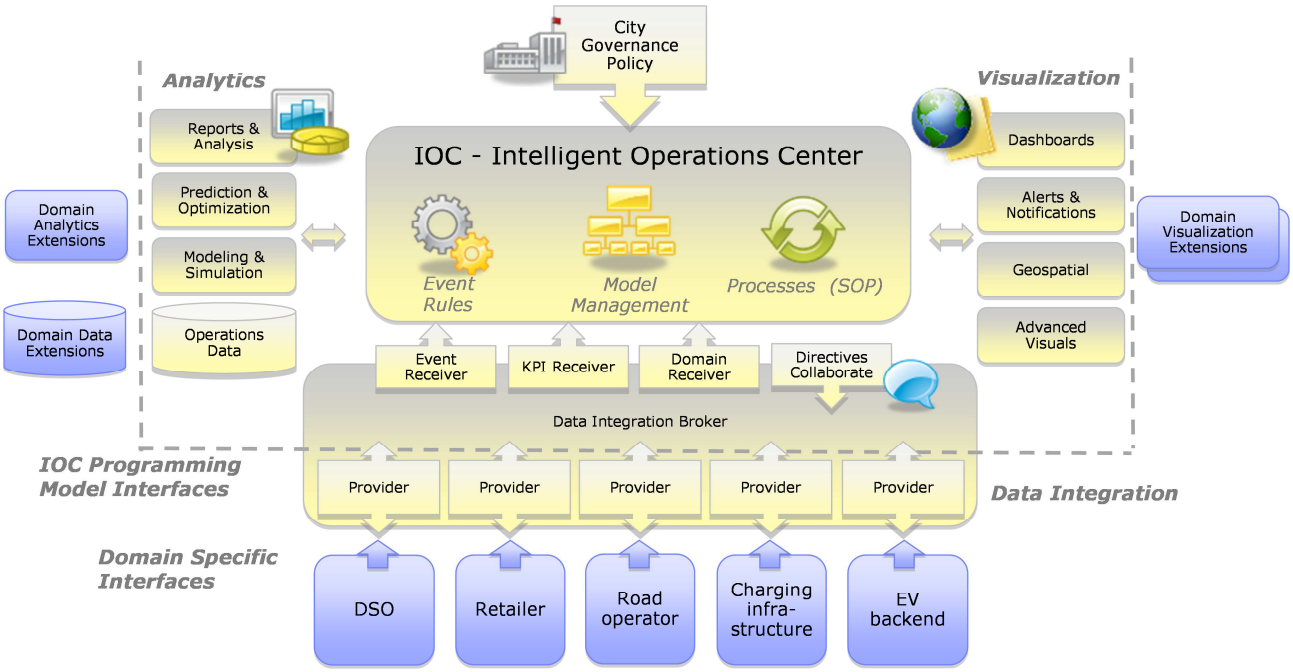

Figure 3: Example of a component model of the IOC

From this component model architecture, the server architecture diagram (Figure 4: Example of a server architecture diagram
) and the server component architecture diagram (Figure 5: Example of a server component model diagram

) may be designed.

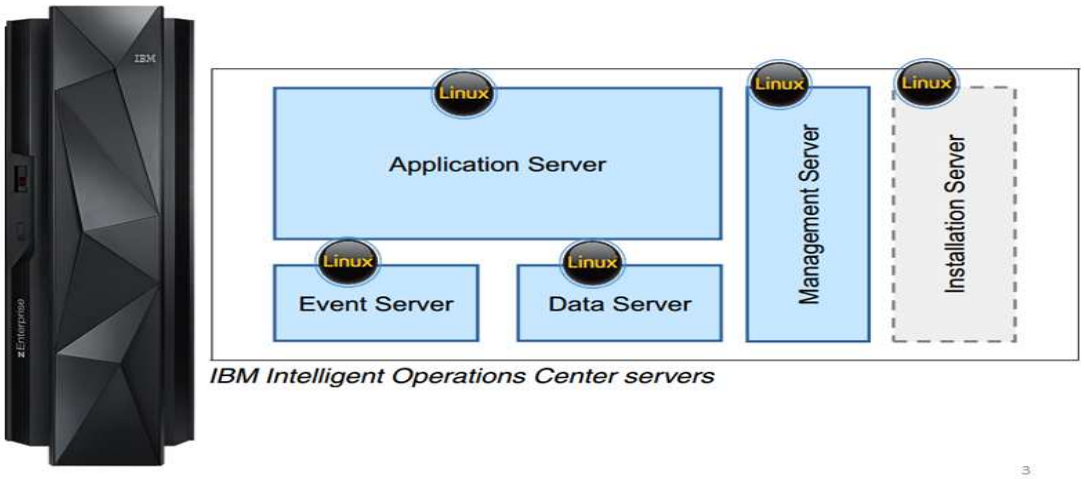

Figure 4: Example of a server architecture diagram

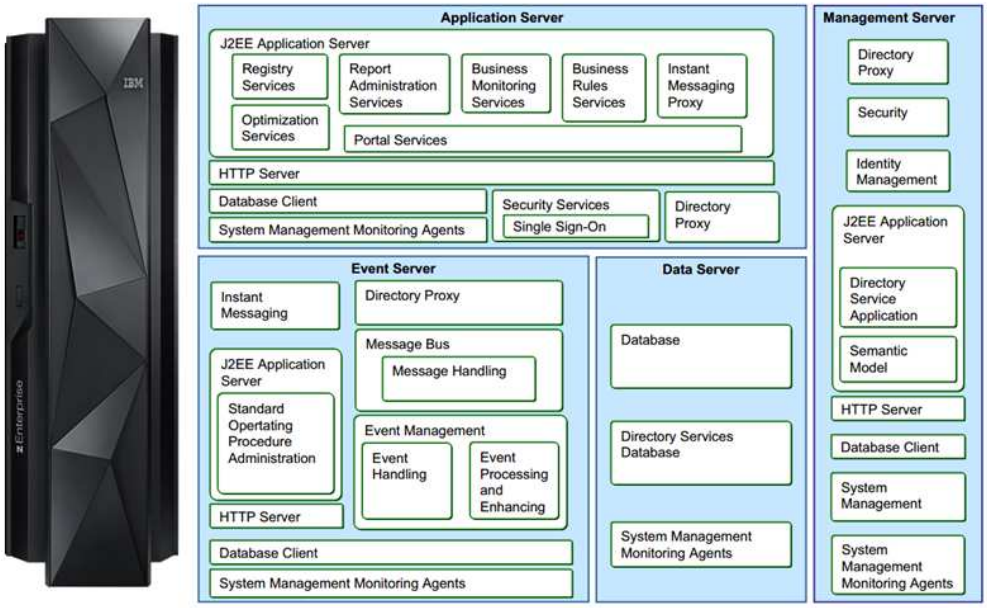

Figure 5: Example of a server component model diagram

Assessment of the technology

The assessment of the implementation of the platform is summarized in the table below. Each indicator can be characterized by an assignment grade. The assessment is explained more in detail below.

Implementation of the solution: Easy

The platform is an existing and proved environment, which has been developed specifically for smart city applications. The FABRIC platform can use existing modules such as communication

and data base. As a consequence, no low-level programming is required. It is mainly configuration and customization of the environment. For example, there is a GIS module which makes it easy to manage maps for congestion management. This type of environments is prepared with many solutions which can be adapted to the needs of the application such as FABRIC.

Interoperability between different car makers: Medium

While the communication of the vehicle with the charging station is an issue, the FABRIC platform will communicate at a higher level with the charging station, the DSO, the Retailer etc. via standard internet protocols. Still, different specific communication modules need to be implemented, which requires an important effort.

Cost of the ICT tool: Low

When analysing the cost of the solution, the Total Cost of Ownership of the tool can be broken down into into 3 main areas: cost of acquisition, cost of operation and application development costs. While the acquisition costs could be considered medium or even high as the server infrastructure should be reliable, this will drive lower costs of operation as the performance and availability management are reached with minimum maintenance effort. The integration by design of the components allows minimizing platform related maintenance procedures. The platform provides a programing model approach that simplifies the application development efforts which will allow fast implementation of the needed modules. Besides, as FABRIC will be just one of many smart city applications, the costs associated to that specific function will be reduced when adding more applications to the platform as it is designed for economies of scale.

Security, Safety: High

The IOC platform is especially developed for high reliability. There are redundant systems in order to minimize down times and data loss. Also data encryption is a standard feature.

Efficiency: High

Similar to the cost, also energy efficiency improved due to the sharing of hardware resources. If FABRIC is just one of many applications, running on the same platform, the high stand-by energy consumption is distributed between many customers. On the other hand, the centralization of information can provide synergy effects, because certain data (for example of the DSO), may be already stored from other smart grid applications.

Usability: Easy

Once implemented, the IOC will operate automatically. Nevertheless, maintenance will be necessary similar to any web service.

Closeness to market: Market ready

The platform is already on the market and applications have been tested in several projects. An ongoing project for the control of district energy flows is the E+ project [3].

4.2.3 Summary Assessment for FABRIC Electric Mobility Platform

4.2.3.1 Baseline Technologies

Table 10: Assessment table for Baseline Technologies

	Service Bus			Process management & Service Orchestration		Complex event processing	
	WSO2 ESB	**Open ESB**	**ServiceMix**	**Apache ODE**	**WSO2 Business Process server**	**WSO2 CEP**	**Esper**
Implementation of the solution	Easy	Medium	Difficult	Medium	Easy	Easy	Medium-High
Interoperability between different solution providers	Easy	Easy	Easy	Easy	Easy	Easy	Medium
Cost of the ICT tools	Low	Low	Low	Low	Low	Low	Low
Security	High	Medium	Medium	Medium	High	Medium	Medium
Safety	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Efficiency (usability and performance)	High	High	Medium	Medium	High	High	Medium
Maintenance	Easy	Medium	Medium	Medium	High	High	Medium
Usability	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Closeness to market	Low effort	Low effort	Low effort	Low effort	Low effort	Low effort	Low effort

Overall assessment	**Highly suitable for FABRIC**	**Suitable for FABRIC**	**Suitable for FABRIC**	**Suitable for FABRIC**	**Highly suitable for FABRIC**	**Highly suitable for FABRIC**	**Suitable for FABRIC**

4.2.3.2 IBM Platform

Table 11: IBM platform assessment

	Assessment grade
Implementation of the solution	Easy
Interoperability between different solution providers	Medium
Cost of the ICT tools	Low
Security	High
Safety	High
Efficiency (usability and performance)	High
Maintenance	N/A
Usability	Easy
Closeness to market	Low effort
Overall assessment	**Suitable for FABRIC**

4.3 Identification

The scope of this section is to describe and evaluate the status of Automatic Vehicle Identification - AVI solutions.

The Automatic Vehicle Identification – AVI represents an innovative solution in the field of the Intelligent Transportation Systems, which permits fully automatic and unique identification of vehicles at specific identification points, offers potential benefits in many fields including fleet control, toll revenue collection, traffic operations, transportation planning, safety and law enforcement.

In this section we describe the main current technologies and their advantages and disadvantages.

Two main technologies are currently being used for Automatic Vehicle Identification: optical and Radio Frequency.

4.3.1 Optical technology

Concerning the Optical, two important technologies are described in the next chapters: barcode readers and Automatic Number Plate Recognition – ANPR.

4.3.1.1 Barcode Readers

The Barcode Readers use barcode decals on the vehicle for identification.

As vehicles pass the barcode reader detects the decal and read the ID code which identifies the vehicle; since the decal is applied to a window, it makes the vehicle itself part of the access control system.

The barcode reader is immune to interference or glare from the sun as well as radio frequency interference from cell phones, radio antennas, power lines and microwave towers.

There are primarily two technologies used to read barcodes. Laser scanners use a laser beam that moves back and forth across the barcode reading the light and dark spaces. Laser scanners have been in use for decades and are capable of scanning barcodes at significant distances (depending on the producer, the environment etc, from 10cm up to 10 meters). CCD (charged coupled device) scanners act like a small digital camera and take a digital image of the barcode which is then decoded. CCD scanners offer a lower cost but are limited to a shorter scan distance.

Barcode reader systems are made up of two items:

- Decals for vehicles.
- Barcode reader.

Decals should be applied to the rear side window of each vehicle on the same side as the barcode reader. Decals should not be placed on the windshield or rear window.

Barcode readers are optical devices, and must be able to “see” the decal in order to read it.

This “must see” policy it’s the first limit of the technology; in example if the decal is applied to a window that rolls down and the window is down, the identification fails.

Below there is an example from the actual market which explains how a barcode reader system can work.

The example regards a Control Access to private or employee parking areas using the Barcode Reader (BR) in standalone mode.

Standalone mode is where the BR handles access grant or deny functions by controlling the gate operator directly. In this example, the only equipment necessary is the reader and a gate operator.

Each authorized vehicle has a barcode decal applied. The ID numbers for vehicles are programmed into the reader and set to either grant or deny access. As the vehicle passes by, the barcode is read and checked against the internal database to see if that vehicle has access. If it does, a relay contact closes to activate the gate. If the vehicle does not have access, the gate does not open and a second relay contact closes that can be used to activate an indicator light or sign informing the driver that access is denied.

The database listing the ID numbers and access privileges in the BR can be reviewed or edited using a laptop computer. Alternately, the reader can be remotely accessed through a modem connected to a telephone line. An on-board log file stores the ID and date/time of entry for the last 2000 vehicles to pass by. This file can be downloaded for review at any time.

Figure 6: Barcode reader example

Assessment of the technology

Implementation of the solution: Difficult

Difficulties in the positioning of the reader, the reader and the TAG must be very near and they must “see” each other.

Interoperability between different providers: Difficult

There is a lot of technology in the market and each provider uses proprietary software and solutions.

Cost of the ICT tool: Low

The tag used is very cheap

Security: High

TAG very easy to steal or to fake

Safety: Low

There is no harm for human

Efficiency: Low

The environmental conditions (dust, rain, snow, etc) and the eventually TAG damage have a big influence on the efficiency of the system

Maintenance: *Medium*

It needs a constant cleaning of the reader and the surface of the tag

Usability: Medium

It needs to be careful when the tag is positioned in front of the reader

Closeness to market: High effort

Normally this solution is used to identify slow object, is not so used in Vehicle identification at high speed and it needs a lot of customization.

4.3.1.2 Automatic Number Plate Recognition – ANPR

Automatic Number Plate Recognition – ANPR, also called Automatic License Plate Recognition – ALPR, is an enforcement technology that optically scans vehicle license plates in order to design an efficient automatic authorized vehicle identification system by using the vehicle number plate.

The developed system first detects the vehicle and then captures the vehicle image. Vehicle number plate region is extracted using the image segmentation in an image. Optical Character

Recognition – OCR technique is used for the character recognition. The resulting data is then used to compare with the records on a database so as to come up with the specific information like the vehicle owner, place of registration, address, etc.

This rapidly deployable, scalable solution uses rugged infrared cameras that connect to leading-edge optical character recognition technology software, allowing conducting surveillance under varied lighting and weather conditions.

ANPR / ALPR process is useful in many scenarios, for example:

- Automatically opening gates / doors for authorized vehicles.
- Traffic monitoring and recognition.
- Toll collection systems.
- Car Park usage monitoring.

Figure 7: Automatic Plate Number Recognition

4.3.1.2.1 ANPR processes

The Automatic Number Plate Recognition – ANPR includes the following processes:

- **Image Handler**. It is responsible for getting raw live images from the IR or color cameras and transforming them into GIF, TIF or JPEG formats used by the OCR process. The Image Handler also sends non-transformed images to ANPR manager process.
- **OCR**. This process finds the plate numbers of the observed vehicle. These results are sent to ANPR Manager process for further handling.
- **ANPR Manager Process**. This module transforms the live images to the images formats used by the Web Server Process and sends them to it. It is responsible for checking whether the found number plate matches the ones given into the black list and white list stored in the Data Base.

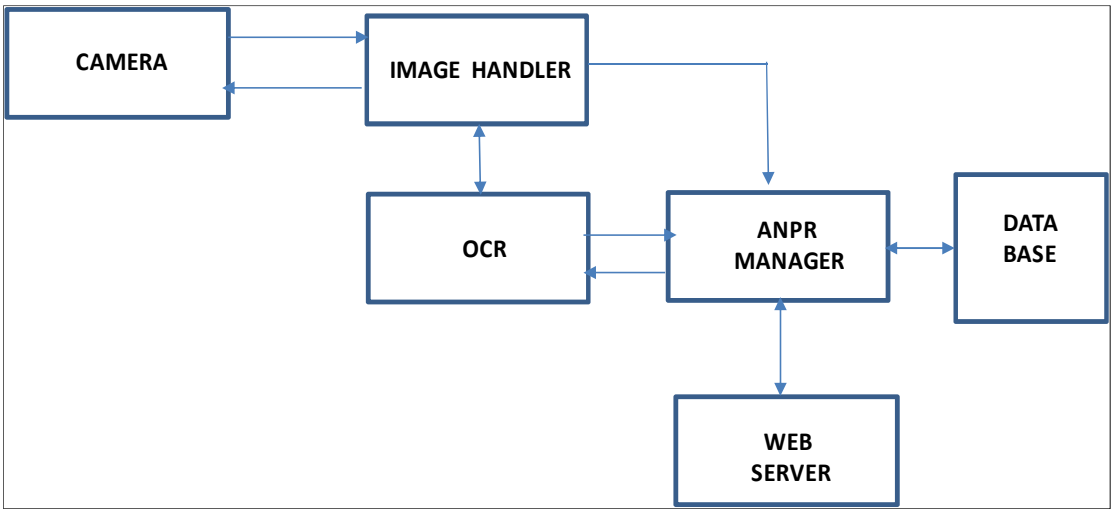

Figure 8: ANPR processes

4.3.1.2.2 ANPR Applications

Car parks

One of the main applications of ANPR is parking automation and parking security: ticketless parking fee management, parking access automation, vehicle location guidance, car theft prevention, "lost ticket" fraud, fraud by changing tickets, simplified, partially or fully automated payment process, among many others.

The benefits of the ANPR in the car park scenario are the following:

- Number plate register. The ticket number, day and the time, and the number plate are linked and registered in the management application.
- Finding a lost ticket. Thanks to the registry of the number plates it is possible to find a lost ticket and to receive the correct amount.
- Ticket interchange is avoided. It is possible to block the exit of a vehicle, if the number plate of the vehicle does not match with the number plate in the entrance ticket.

Access control

Access control in general is a mechanism for limiting access to areas and resources based on users' identities and their membership in various predefined groups. Access to limited zones, however, may also be managed based on the accessing vehicles alone, or together with personal identity. License plate recognition brings automation of vehicle access control management, providing increased security, car pool management for logistics, security guide assistance, event logging, event management, keeping access diary, possibilities for analysis and data mining.

Traffic control

The ANPR technology is able to recognize the number plate of vehicles that transit up to 200 km/h with a reliability of 95%. Thanks to these performances, the use of ANPR for traffic control has increased in the last years.

Data collected by license plate recognition systems can be used in many ways after processing: feeding back information to road users to increase traffic security, helping efficient law enforcement, optimizing traffic routes, reducing costs and time, etc.

Figure 9: Traffic monitoring

Toll enforcement

Road Tolling means that motorists pay directly for the usage of particular segment of road infrastructures. Efficient road tolling increases the level of related road services by reducing travel time overhead, congestion and improve roadways quality. Also, efficient road tolling reduces fraud related to non-payment, makes charging effective, reduces required manpower to process events of exceptions. License plate recognition is mostly used as a very efficient enforcement tool, while there are road tolling systems based solely on license plate recognition too (see video tolling)..

Figure 10: Toll Plaza lanes

Video tolling

Video tolling is a technique for toll collection using video or still images of a vehicle's license plate to identify the vehicle for payment.

The system permits the road payment without the need for a tag in the vehicle.

There are two forms of video tolling: "Registered" and "Unregistered" accounts. In Registered Video Tolling, the user must first register the vehicle's plates with the tolling agency prior to using the toll system. The toll system will then associate the plate images with the account and debit the amount of the toll from the account. Unregistered systems lookup the vehicle registration information from the State DMV database and send a bill to the address in the DMV database.

Figure 11: Video tolling on M50 motorway

Assessment of the technology

Implementation of the solution: Medium

Easy installation but there is a lot of options in cameras regulation. Each camera have to be configured for the place where have to work.

Interoperability between different providers: Medium

Very high interoperability in HW and cameras but each provider uses a proprietary SW.

Cost of the ICT tool: Low

The cost it is quite low because there is a strong competition on the ANPR market

Security: High

Although the solution is secure in itself, it relies on the vehicle plates which are easy to fake.

Safety: Medium

Totally safe.

Efficiency: Medium

The standard of the market is 98,5% of good identification in normal environment condition.

Maintenance: *Medium*

If the installation is doing well very small maintenance is required, some planned cleaning of the camera is needed.

Usability: Easy

A good tuning of the camera during the installation assure a totally automatic system.

Closeness to market: Low effort

There is a strong completion on this market so almost any solution is easy to find.

4.3.2 Radio Frequency Identification – RFID

Radio Frequency Identification – RFID technology consists of tags and readers that assist in the tracking of the vehicles.

The tags either passively or actively communicate with roadside readers to identify vehicle ownership.

4.3.2.1 Tags

RFID tags can be either passive, active or battery-assisted passive. An active tag has an on-board battery and periodically transmits its ID signal. A battery-assisted passive (BAP) has a

small battery on board and is activated when in the presence of an RFID reader. A passive tag is cheaper and smaller because it has no battery. However, to start operation of passive tags, they must be illuminated with a power level roughly three magnitudes stronger than for signal transmission. That makes a difference in interference and in exposure to radiation.

Tags may either be read-only, having a factory-assigned serial number that is used as a key into a database, or may be read/write, where object-specific data can be written into the tag by the system user.

Figure 12: 5.8 GHz tag

RFID tags contain at least two parts: an integrated circuit for storing and processing information, modulating and demodulating a radio-frequency (RF) signal, collecting DC power from the incident reader signal, and other specialized functions; and an antenna for receiving and transmitting the signal. The tag information is stored in an EPROM. The RFID tag includes either a chip-wired logic or a programmed or programmable data processor for processing the transmission and sensor data, respectively.

An RFID reader transmits an encoded radio signal to the tag. The RFID tag receives the message and then responds with its identification and other information. This may be only a unique tag serial number, or may be product-related information such as a stock number, lot or batch number, production date, or other specific information.

4.3.2.2 Readers

A Passive Reader Active Tag (PRAT) system has a passive reader which only receives radio signals from active tags (battery operated, transmit only). The reception range of a PRAT system reader can be adjusted from 0.30 – 609.60 m, allowing flexibility in applications such as asset protection and supervision.

An Active Reader Passive Tag (ARPT) system has an active reader, which transmits interrogator signals and also receives authentication replies from passive tags.

An Active Reader Active Tag (ARAT) system uses active tags awoken with an interrogator signal from the active reader. A variation of this system could also use a Battery-Assisted Passive (BAP) tag which acts like a passive tag but has a small battery to power the tag's return reporting signal.

Fixed readers are set up to create a specific interrogation zone which can be tightly controlled. This allows a highly defined reading area for when tags go in and out of the interrogation zone. Mobile readers may be hand-held or mounted on carts or vehicles.

Figure 13: Multilane free flow system equipped with 5.8 GHz readers

Frequencies

RFID uses electromagnetic energy in the Radio Frequency (RF) part of the electromagnetic spectrum, to carry information between an RFID tag and an RFID reader.

RFID is most often used in one of these four frequency bands:

- Low Frequency (LF) 120 to 154 KHz band
- High Frequency (HF) 13.56 MHz
- Ultra High Frequency (UHF) 433 MHZ and 860 to 956 MHz band
- Microwave Frequency 2.45 to 5.8 GHz band

Table 12: RFID Frequency Bands

RFID frequency bands

Band	Regulations	Range	Data speed	Remarks
120–150 kHz (LF)	Unregulated	10 cm	Low	Animal identification, factory data collection
13.56 MHz (HF)	ISM band worldwide	10 cm - 1 m	Low to moderate	Smart cards (MIFARE, ISO/IEC 14443)
433 MHz (UHF)	Short Range Devices	1–100 m	Moderate	Defence applications, with active tags
865-868 MHz (Europe) 902-928 MHz (North America) UHF	ISM band	1–12 m	Moderate to high	EAN, various standards
2450-5800 MHz (microwave)	ISM band	1–2 m	High	802.11 WLAN, Bluetooth standards
3.1–10 GHz (microwave)	Ultra wide band	to 200 m	High	requires semi-active or active tags

Assessment of the technology

Implementation of the solution: Difficult

Difficulties in the positioning of the reader, the reader and the TAG must be very near

Interoperability between different providers: Difficult

There is a lot of technology in the market and each provider uses proprietary software and solutions.

Cost of the ICT tool: Medium

The tag used is available in many different versions covering all the price levels.

Security: High

Good security of the data stored in the tag but the system rely on movable tag.

Safety: High

There is no risk

Efficiency: Medium

Very good efficiency till the distance between the reader and the tag is few centimetres.

Maintenance: *Easy*

Very small maintenance needed

Usability: Easy

It needs to be careful when the tag is positioned in front of the reader

Closeness to market: Low effort

Normally this solution is used to identify slow object, is not so used in Vehicle identification at high speed and it needs a lot of customization.

4.3.3 Dedicated Short-Range Communications

Dedicated Short-Range Communications (DSRC) provides communications between a vehicle and the roadside in specific locations, for example toll plazas. They may then be used to support specific Intelligent Transport System applications such as Electronic Fee Collection.

DSRC are for data-only systems and operate on radio frequencies in the 5,725 MHz to 5,875 MHz Industrial, Scientific and Medical (ISM) band. DSRC systems consist of Road Side Units (RSUs) and the On Board Units (OBUs) with transceivers and transponders. The DSRC standards specify the operational frequencies and system bandwidths, but also allow for optional frequencies which are covered (within Europe) by national regulations.

DSRC systems are used in the majority of European Union countries, but these systems are currently not fully compatible each other. Therefore, standardization is essential in order to ensure pan-European interoperability, particularly for applications such as electronic fee collection, for which the European imposes a need for interoperability of systems.

The actual systems are quite similar in the hardware specification (especially for the electromagnetic part as shown in the next table), but each provider use a proprietary communication protocol, so it's quite difficult for a third part system integrator to merge equipment or sub-systems coming from different providers.

Standardization will also assist with the provision and promotion of additional services using DSRC, and help ensure compatibility and interoperability within a multi-vendor environment.

Active DSRC is the road-to-vehicle radio communication method, and it is based on the international standard as specified by Annex 1 on Recommendation ITU-R M.1453. The main

features of Active DSRC are high reliability and large capacity. It can provide very high level of accuracy for the road-to-vehicle communication, without any lowering by weather conditions. As actually proved in the highways where is implemented, the communication error rate of Active DSRC is less than one in every 100 thousands transactions.

Thus, Active DSRC is one of the most reliable road-to-vehicle communication methods available in the market today. Also, Active DSRC has the large capacity for road-to-vehicle communication, since it has wide communication area and high-speed communication. This enables the roadside equipment to interactively transmit and receive large volumes of data with multiple vehicles. Thus, the Active DSRC is the most suitable for non-stop toll collection system, especially for multi-lane free-flow toll collection system, where vehicles can pass the toll gantry without reducing speed.

One Active DSRC antenna can cover up to three free-flow lanes. Moreover, Active DSRC can be the base of wide applicability for future ITS services.

Because of Active DSRC and smart card adoption, flexibility becomes the most important selling point of Electronic Tool Collection (ETC) regarding the payment method, it can adapt to both pre-paid system and post-paid system. Also, it can meet requirements for tollgate-type toll collection, as well as free-flow type toll collection, and so it can be installed either at toll plaza and/or main lane gantry. Furthermore, since its adoption of a smart card, it can be used for Touch-and-Go system. So, it can correspond flexibly to each development stage of toll collection scheme. For example, when traffic volume is low, such as rural area, it is not necessary to install ETC system, but, for closed system toll road, one must install the same toll collection system at both ends, regardless of traffic volume. So, with ETC system, one can install ETC system at urban area, where traffic volume is high, and use Touch-and Go system at rural area, where traffic volume is low. By this way, the introduction cost of ETC can be reduced drastically. Moreover, introduction of Global ETC can enable appropriate apportionment of toll revenue among different toll road operators. It is also possible to offer various type of discount rate system, such as mileage discount, nighttime discount, etc. Furthermore, we present examples of what DSRC can provide for transportation applications.

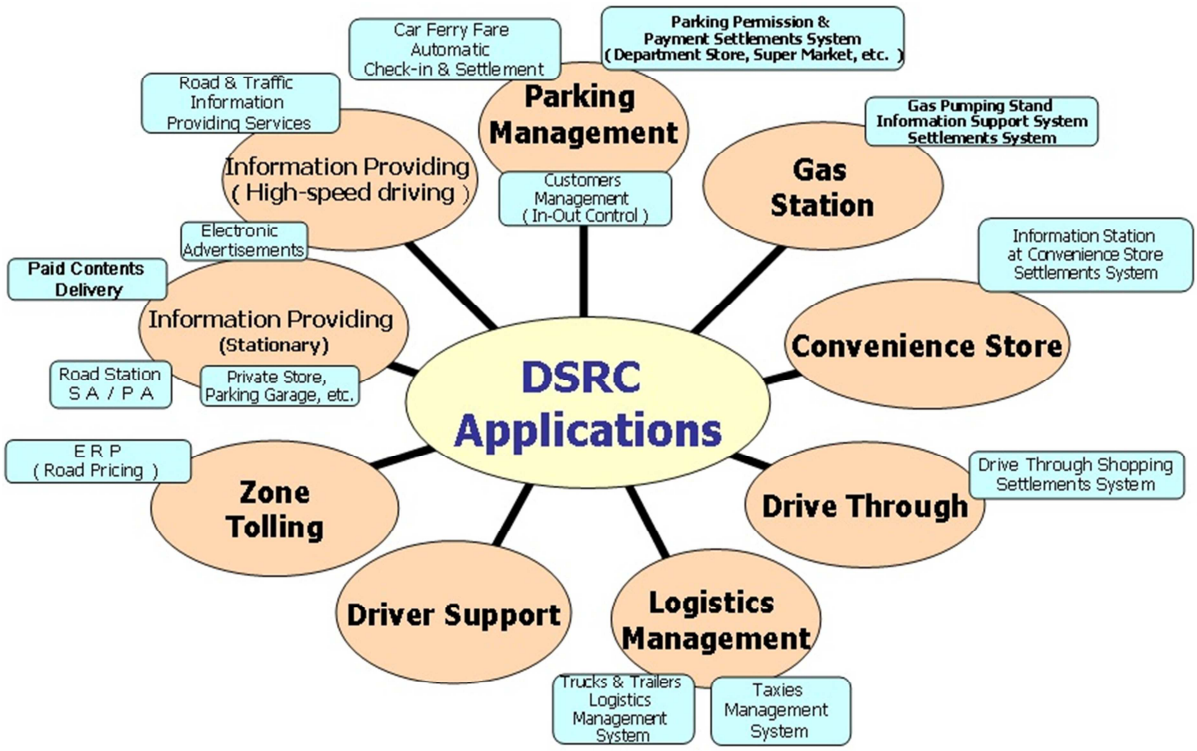

Figure 14: DSRC applications

The following table shows comparison of DSRC specification of three major areas. Because the OBU has a RF oscillator, Active-DSRC can realize flexible communication zone from narrow area to wide area (max. 30m). Thus Active-DSRC characters realize real-time IC card access in the communication area as well as other ITS applications.

Table 13: Comparison of Primary DSRC technologies

Region / Item		Europe	Asia	North America
1.International Standard		ITU-R M.1453-2 (Layer-1) ISO 15628 (Layer-2,7)		None
				ISO 21215 (CALM M5)
2. Regional standard		[CEN Standard] -ENV 12253(L-1)	ARIB-STD-T75 (Japan) TTAS06-	ASTM E2158-01
		-ENV 12795(L-2) -ENV 12834(L-7)	GB/T20851-2007 (China)	ASTM E2213-03 IEEE 802.11p, 1609 (WAVE soon
3.Communication method		Passive	Active	Passive/Active
				Active (WAVE)
4. Radio Frequency		5.8GHz	5.8G Hz	915MHz
				5.9GHz(WAVE)
5.Data Rate	***Down***	500Kbps	1Mbps 4Mbps (Japan)	500Kbps
				2 ~ 27Mbps (WAVE)
	Up	250Kbps	1Mbps 4Mbps (Japan)	500Kbps
				2 ~ 27Mbps (WAVE)
6. Communication Range (Foot print)		Up to 5m	4m for Single-lane 16m for Multi-lane 30m for ITS Applications	10m
				1Km (WAVE)
7. Adopted Countries		European Countries, etc.	Japan, Korea, (China)	USA, Canada

Assessment of the technology

Implementation of the solution: Medium

Some civil works needed during installation but after that the system is normally ready to work.

Interoperability between different providers: Easy

Many European standards are developed to cover almost any of the DSRC applications.

Cost of the ICT tool: Medium

There is a strong competition on the DSRC market but the cost of the solution is in a medium range due to the complexity of the equipment installed

Security: High

The encryption method of the data transfer and the coverage of a wide area with each antenna make this solution one of the most reliable.

Safety: High

All the equipment has to satisfy the Europeans safety level for being sold in the DSRC market.

Efficiency: High

The standard of the market is 99,5% of good identification with vehicle running up to 180 km/h.

Maintenance: *Easy*

Very small maintenance needed.

Usability: Easy

The system works with any effort or action on the user side.

Closeness to market: Low effort

There is a strong completion on this market so almost any solution is easy to find.

4.3.4 Summary Assessment for AVI Technologies

Automatic Number Plate Recognition - ANPR is increasingly used by the operators to enhance the road management.

While ANPR cameras and supporting technology have improved significantly in recent years, they rely completely on license plate accuracy. Yet license plate fraud and the cloning of vehicle identity by changing plates or altering characters is on the increase, seriously impacting ANPR effectiveness.

A highly secure method of vehicle identification uses the – DSRC fitted to, or embedded within, the license plate.

A unique identifier is transmitted from the DSRC tag which is compared with what the ANPR camera is seeing. An alert is created where there is a mismatch or no DSRC is present. This can then trigger a response either for an enforcement team at the location or a follow up response from the back-office.

Combined ANPR and DSRC technology provides the most secure and validated vehicle identification system, so this will be the technology implemented in the Italian Test Site for the FABRIC project.

Table 14: Summary assessment table of AVI technologies

	Barcode reader	ANPR	RFID	DSRC
Implementation of the solution	Difficult	Medium	Difficult	Medium
Interoperability between different solution providers	Difficult	Medium	Difficult	Easy
Cost of the ICT tools	Low	Low	Medium	Medium
Security	High	High	High	High
Safety	Low	Medium	High	High
Efficiency (usability and performance)	Low	Medium	Medium	High
Maintenance	Medium	Medium	Easy	Easy
Usability	Medium	Easy	Easy	Easy
Closeness to market	High effort	Low effort	Low effort	Low effort
Overall assessment	**Not suitable for FABRIC**	**Highly suitable for FABRIC**	**Suitable for FABRIC (Static recharge Scenario)**	**Highly suitable for FABRIC**

4.4 Routing

Developing a software service for enhanced navigation supporting Electrical Vehicle Dynamic Charging (EVDC) requires building a navigation system which is aware of the typical features of the target system (e.g., number, power and length of dynamic charging lanes, average / expected traffic at different times, etc.). To the best of our knowledge, there are no systems providing these functionalities, while there are excellent tools on the market for general navigation. Thus, the idea is to build atop of such existing maps and routing services. This section reviews existing commercial solutions for routing and mapping support. So, differently than most of the technologies presented in this deliverable, here we are speaking of products on the market that need being enhanced through ad-hoc algorithms to be developed in FABRIC.

We focus on service oriented software solutions – particularly HTTP-based web-services -, since they represent the state of the art from the architectural point of view. Web Services provide an easy way to accomplish specific tasks from virtually any programming environment.

Wikipedia[2] provides an interesting high-level outlook for comparing map services, listing providers such as: Google Maps, Yahoo! Maps (now migrated to Nokia Here), Bing Maps, MapQuest, OpenStreetMap, Nokia Here, Apple Maps. The outlook synthetizes the products along several dimensions such as: license options, supported browsers, viewing interface, data, search and direction facilities, mobile support, etc.

In the following, we go in the detail of the features provided by the most prominent providers, in the light of the FABRIC requirements.

4.4.1 Google Maps Web Services[3]

Google Maps is a desktop and mobile web mapping service application and technology provided by Google, offering satellite imagery, street maps, and Street View perspectives, as well as functions such as a route planner .

Google Maps is coded almost entirely in JavaScript and XML. By using the Google Maps API, it is possible to embed Google Maps site into an external website, on to which site specific data can be overlaid. GoogleMaps support Javascript (Google Maps JavaScript API v3[4],), Android, iOS, and provide services for retrieving static map images, and web services for performing geocoding, generating driving directions, and obtaining elevation profiles. Over 1,000,000 web sites use the Google Maps API, making it the most heavily used web application development API[5].

[2] http://en.wikipedia.org/wiki/Comparison_of_web_map_services
[3] https://developers.google.com/maps/documentation/webservices
[4] https://developers.google.com/maps/documentation/javascript
[5] http://www.programmableweb.com/apis/directory

The Google Maps APIs give developers several ways of embedding Google Maps into web pages, and allows for either simple use or extensive customization.

The Google Maps Web Services (GMWS) are a collection of HTTP interfaces to Google services providing geographic data for your maps applications. Services are provided both through a SOAP or a REST interface. GMWS provides five categories of Application Programming Interfaces (APIs), such as the following: Directions API, Distance Matrix API, Elevation API, Geocoding API and Time Zone API.

Accessing the Directions service is asynchronous, since the Google Maps API needs to make a call to an external server.

Detailed descriptions, reference documentation and examples are provided online. Support is offered through Stack Overflow, a collaboratively-edited question and answer site for programmers.

The Google Maps API is free for commercial use, provided that the site on which it is being used is publicly accessible and does not charge for access, and is not generating more than 25 000 map accesses a day. Sites that do not meet these requirements can purchase the Google Maps API for Business.

Assessment of the technology

Implementation of the solution: Medium

Necessity to develop algorithms atop of very widely spread, known and rich data and services.

Interoperability between different solution providers: Easy

Use of standard languages (Javascript, Android, etc.) and protocols (REST, SOAP)

Cost of the ICT tool: Low

Google services for limited traffic are for free. This is the case of the FABRIC prototype. Issues may come for the actual product, for which a proper business model will need to be defined.

Security: N/A

Safety: N/A

Efficiency: High

Google APIs programming is a very efficient technique for building applications atop.

Maintenance: High

Google APIs are a well established and supported tool.

Usability: High

Google APIs are a well-established and supported tool

Closeness to market: Medium

Ad-hoc algorithms are needed to be developed in order to implement a navigator supporting Electrical Vehicle Dynamic Charging (EVDC-N). Furthermore, transforming a Google Maps-based prototype into a product mostly involves commercial issues due to the licensing.

4.4.2 Bing Maps

Bing Maps is a web mapping service provided as a part of Microsoft's Bing suite of search engines and powered by the Bing Maps for Enterprise framework.

The Bing™ Maps Services Application Programming Interface (API) provides an interface to perform tasks such as creating a static map with pushpins, geocoding an address, retrieving imagery metadata, or creating a route. Services are provided both through a SOAP or a REST interface. Services include clusters of APIs, such as: locations, elevations, imagery, routes and traffic.

The Routes API can be used to create a route that includes two or more locations and to create routes from major roads. You can create driving or walking routes. Driving routes can include traffic information. Routes can also be overlaid on map imagery (REST Services Imagery API).

Transaction accounting is provided when using the Bing Maps REST Services. Licensing looks more complex but also more flexible than in the case of google maps[6]. Commercial licenses are requested for traffic above 50,000 requests per day even for apps freely available to consumers.

Detailed descriptions, reference documentation and examples are provided online. The Bing developer community involves forums and blogs.

Assessment of the technology

Implementation of the solution: Medium

Need to develop algorithms atop of well-established and rich data and services.

Interoperability between different solution providers: Easy

Use of standard languages (Javascript, Android, etc.) and protocols (REST, SOAP)

[6] http://www.earthware.co.uk/blog/mapping-apis-google-maps-vs-bing-maps-part-2-licensing/#.VCVsVBJ0zWI

Cost of the ICT tool: Low

Bing services for limited traffic are for free. This is the case of the FABRIC prototype. Issues may come for the actual product, for which a proper business model will need to be defined.

Security: N/A

Safety: N/A

Efficiency: Medium

Bing APIs programming is an efficient technique for building applications atop.

Maintenance: High

Bing APIs are a well-established and supported tool.

Usability: High

Bing APIs are a well-established and supported tool

Closeness to market: Medium

Ad-hoc algorithms are needed to be developed in order to implement navigator a supporting Electrical Vehicle Dynamic Charging (EVDC-N). Furthermore, transforming a prototype into a Bing-based product mostly involves commercial issues due to the licensing.

4.4.3 ARCGIS

ARCGIS for developers allows building applications for web, mobile and desktop with ESRI's cloud services, developer APIs, ready-to-use content and self-hosted solutions. Particularly, ARCGis provides powerful APIs for visualization, geo-coding, directions, real-time processing of sensor data, custom data storage and imagery.

The directions service allows generating routes between any number of places. Is it also possible to generate optimal routes to the nearest one of several places, and calculate areas accessible in a given amount of time. The direction service is available through a REST interface. SDKs and APIs are available for Javascript, Android, iOS.

Detailed descriptions, reference documentation and examples are provided online. Developer community involves forums and blogs, also on Stack Overflow. Better support levels are purchasable.

License terms are based on the number of map transactions and/or geosearches generated by an application per month, through a service credit system.

Assessment of the technology

Implementation of the solution: Medium

Necessity to develop algorithms atop of well-established and rich data and services.

Interoperability between different solution providers: Easy

Use of standard languages (Javascript, Android, etc.) and protocols (REST)

Cost of the ICT tool: Medium

The ESRI server products are payable and the service credit system involves a subscription and payment per use.

Security: N/A

Safety: N/A

Efficiency: Medium

ArcGis APIs programming is an efficient technique for building applications atop.

Maintenance: High

ArcGis APIs are a high quality software development tool.

Usability: High

ArcGis APIs are a high quality software development tool

Closeness to market: Medium

Ad-hoc algorithms are needed to be developed in order to implement navigator a supporting Electrical Vehicle Dynamic Charging (EVDC-N). Also, transforming a prototype into a product involves a license upgrade due to traffic increase.

4.4.4 HERE Maps

HERE REST APIs provide access to variety of map data and functionalities. Developers can use HERE Rest APIs to perform tasks ranging from batch geocode requests, advanced traffic incident reports to creating an isoline route (i.e., the set of all possible travel routes from a start point to a given distance).

HERE maps provides solutions for GIS and government clients and powers major mapping providers, such as Bing and Yahoo! Maps.

Native SDKs are available for Android, iOS, Windows Phone, and Qt.

REST APIs are available for such services as: map tiles, map images, venue maps, routing (also enterprise and matrix), geocoding, traffic and places.

The HERE Routing API calculates routes between two or more locations and provides additional route-related information, such as real-time traffic updates.

Route information consists of a graphical representation of the route and a detailed turn-by-turn route description. It enables mapping applications to render the geographical representation of the route together with the map data, so that the route is displayed on the map.

The Routing API is customizable so that the route calculation and additional information can be adapted to both consumer and enterprise applications and specific application use cases. Public Transport TimeTable Routing and Traffic Enabled Routing are features that may be subject to premium pricing.

Detailed descriptions, reference documentation and user guides are provided online.

Two main licensing options are available for the HERE Maps APIs:

- Base – Free monthly access to basic Maps, Directions and Places functionality for use on both commercial and non-commercial websites, subject to maximum daily usage limits. Only applicable for consumer-facing applications, i.e., applications where the end customers are business users are explicitly excluded.
- Commercial (Paid) – Full-featured solutions that meet the volume requirements and include Service Level Agreement (SLA).

Assessment of the technology

Implementation of the solution: Medium

Necessity to develop algorithms atop of well-established and rich data and services.

Interoperability between different solution providers: easy

Use of standard languages (Javascript, Android newly released, etc.) and protocols (REST)

Cost of the ICT tool: Low

Here services for limited traffic (and moderate service levels) are free. This is the case of the FABRIC prototype. Issues may come for the actual product, for which a proper business model will need to be defined.

Security: N/A

Safety: N/A

Efficiency: Medium

Here APIs programming is an efficient technique for building applications atop.

Maintenance: High

Here APIs look well supported.

Usability: Medium

Here APIs are a good quality software development tool, but support seems less extensive than other tools like google maps

Closeness to market: Medium

Ad-hoc algorithms are needed to be developed in order to implement navigator a supporting Electrical Vehicle Dynamic Charging (EVDC-N). Also, transforming a prototype into a product involves licensing for traffic and Service Level Agreement.

4.4.5 MapQuest

MapQuest is an online web mapping service owned by AOL. MapQuest is one of the pioneers in online mapping and holds a significant market share in the U.S.

From a programming point of view, APIs are provided for Javascript, mobile Flash, iOS and Android. Many MapQuest services are featured within our client-side APIs (i.e. JavaScript), however, you they can be used directly as well. Web services provide support to directions, geo-coding, search, static maps, and traffic.

APIs and Web Services are available on both Licensed and Open Data. Licensed data is regularly updated by commercial vendors and is used by default on MapQuest.com and MapQuest mobile products. Open data is crowdsourced through theOpenStreetMap community and features fast updates, amazing map detail in some areas and flexible terms of use.

The MapQuest Directions API allows accessing the routing algorithms that power MapQuest.com through simple HTTP requests. The Directions API supports various types of requests, such as fastest and shortest routes, pedestrian, bicycle, and multimodal routes. Optimized routing, date and time routing, and route matrix functionality is also available through the API. Community Edition users can make up to 5,000 free directions requests per day.

Detailed descriptions, reference documentation and examples are provided online. Developer community involves forums and blogs

The Enterprise Edition licenses include a service-level agreement (SLA), access to technical support engineers 24/7/365 emergency support, and no limits placed on the number of directions requests that can be made per day.

Assessment of the technology

Implementation of the solution: Medium

Necessity to develop algorithms atop of well-established and rich data and services.

Interoperability between different solution providers: easy

Use of standard languages (Javascript, Android newly released, etc.) and protocols (REST, SOAP)

Cost of the ICT tool: Low

MapQuest services for limited traffic (and moderate service levels) are free. This is the case of the FABRIC prototype. Issues may come for the actual product, for which a proper business model will need to be defined.

Security: N/A

Safety: N/A

Efficiency: High

MapQuest APIs programming is a highly efficient technique for building applications atop.

Maintenance: High

MapQuest APIs are well supported.

Usability: High

MapQuest APIs are a highly usable quality software development tool

Closeness to market: Medium

Ad-hoc algorithms are needed to be developed in order to implement navigator a supporting Electrical Vehicle Dynamic Charging (EVDC-N). Also, transforming a prototype into a product involves licensing for traffic and Service Level Agreement.

4.4.6 OpenStreetMap

OpenStreetMap (OSM) is a collaborative project to create a free editable map of the world. OpenStreetMap has an Editing API for fetching and saving raw geodata from/to the OpenStreetMap database.

OpenStreetMap is built by a community of mappers that contribute and maintain data about roads, trails, cafés, railway stations, and much more, all over the world. data quality varies worldwide.

OpenStreetMap is open data, licensed under the Open Data Commons Open Database License (ODbL).

OpenStreetMap data are free to use it for any purpose as long as you credit OpenStreetMap and its contributors. If data are alter or applications built upon them in certain ways, results may be distributed only under the same licence.

The cartography in OSM map tiles, and documentation, are licensed under the Creative Commons Attribution-ShareAlike 2.0 license (CC BY-SA).

Although OSM is open data, OSM cannot provide a free-of-charge map API for third-party developers. Specific API Usage Policy have been set up.

Concerning routing, it is currently not possible to do this directly on the openstreetmap.org website, however, there are a number of external sites that allow you to do this based on OpenStreetMap data. Examples are: OSRM, Mapquest Open, Yournavigation, OpenRouteService. There are also more specialised forms such as for cycling in the UK such as cyclestreets.

Furthermore, there are a number of applications that allow using OpenStreetMap data for navigation on smart phones or sat-nav such as: Mapfactor free for sat-nav devices, Skobbler for iPhone, Navmii for iPhone, Garmin OSM maps and many more for all types of devices.

There are also plans to eventually include directions on openstreetmap.org, but they are still in development.

Thus, OpenStreetMap is not a suitable solution for FABRIC, at present.

4.4.7 Summary Assessment for Routing

The FABRIC enhanced navigation supporting Electrical Vehicle Dynamic Charging (EVDC) will need mapping and routing functionalities as a fundamental basis. Our feasibility analysis revealed that this can be achieved through one of the several high quality mapping services that are already available on the market.

In particular, we can say that the most widespread state of the art solutions we have analysed (i.e., Google Maps, Bing Maps, Nokia Here, ArcGIS) are “suited for FABRIC”. However, our first choice is MapQuest, that we catalogue as “very suited for FABRIC”. MapQuest, in fact, builds upon the OpenStreet Map open technology. MapQuest routing features both open data and proprietary data solutions, thus allowing a flexibility that could be fruitfully explored inside FABRIC and in view of a product development and evolution.

Table 15: Summary assessment table of Routing technologies

	Google Maps Web services	Bing Maps	ARCGIS	HERE Maps	MapQuest
Implementation of the solution	Medium	Medium	Medium	Medium	Medium
Interoperability between different solution providers	Easy	Easy	Easy	Easy	Easy
Cost of the ICT tools	Low	Low	Medium	Low	Low
Security	N/A	N/A	N/A	N/A	N/A
Safety	N/A	N/A	N/A	N/A	N/A
Efficiency (usability and performance)	High	Medium	Medium	Medium	High
Maintenance	High	High	High	High	High
Usability	High	High	High	Medium	High
Closeness to market	Medium	Medium	Medium	Medium	Medium
Overall assessment	**Suitable for FABRIC**	**Suitable for FABRIC**	**Suitable for FABRIC**	**Suitable for FABRIC**	**Highly suitable for FABRIC**

4.5 Connected car and HMI

The objective of this section is to describe and evaluate the status of the car connection solutions.

Until the last two years, a standard to create a system or interface for the interaction between the users and vehicles was not available. Each automotive company provides its custom solutions and in most cases these solutions are incompatible with each other; therefore, developers have to create a version for each company, incrementing the costs.

With the popularization of mobile smart devices, OEM companies are rethink their strategy to adopt the mobile user experience in their in-vehicle infotainment systems, combining the interaction among the car and the mobile devices.

In this section, the main current solutions as well as their advantages and disadvantages are described.

4.5.1 MirrorLink

Figure 15: Sample screens of MirrorLink

'*MirrorLink is a device interoperability standard that offers integration between a smartphone and a car's infotainment system. MirrorLink transforms smartphones into automotive application platforms where apps are hosted and run on the smartphone while drivers and passengers interact with them through the steering wheel controls, dashboard buttons and touch screens of their car's In-Vehicle Infotainment (IVI) system.*

MirrorLink utilizes a set of well-established, non-proprietary technologies such as IP, USB, Wi-Fi, Bluetooth, Real-Time Protocol (RTP, for audio) and Universal Plug and Play (UPnP). In addition, MirrorLink uses Virtual Network Computing (VNC) as the baseline protocol to display the user interface of the smartphone applications on the infotainment system screens and to communicate user input back to the mobile device'. [4]

The main reason to create MirrorLink is to define a standard for connect car with other system devices for provide to all companies and developers a common base to create software and hardware that can be interoperate among themselves.

This system is created in 2010 by Nokia as a research project in their Nokia Research Center in Palo Alto, US. Currently, it is maintained and developed by Car Connectivity Consortium (CCC) that is responsible to approve the new partners request and new members of CCC and also to define the roadmap of the evolution of MirrorLink.

Main features:

- Common API to all members of CCC and authorize developers
- Possibility to register as new member in CCC paying annual fee
- Device developer program that provided the possibility to create new devices that follow the rules of CCC after previous approval of CCC members.
- Software developer program. Authorization can be requested to develop new software for MirrorLink system following their API and rules.
- Participated by main automotive companies (GM, Honda, Hyundai, Toyota, and Volkswagen) and smartphone makers (LG, Sony, HTC, and Samsung).
- The approval process of MirrorLink apps is transparent and open, in order to grant that none is blocked based on particular interests of the partners
- Compatibility with main mobile systems as Symbian, Microsoft, BlackBerry and Android. In the future is possible to integrate iPhone systems (depending on Apple strategy).

Assessment of the technology

Implementation of the solution MirrorLink: Medium

MirrorLink has available a developer program to create software and hardware for the cards that use this system. The documentation is clear but have a number of rules that is required to follow that the hardware or software is approved by the consortium and can be available to all partners to use.

Interoperability between different car makers MirrorLink: Easy

All partners that work in this solution follow the same rules and have the same documentation to implement all requirements that must follow that provided a valid software or hardware for MirrorLink.

Cost of the ICT tools MirrorLink: Low

‘For Core and Charter members of CCC there is no fee associated with listing your product. There is a small listing fee associated with products certified by Adopter members. Testing fees need to be negotiated directly with any of our Authorized Testing Laboratories’ [5]

Security MirrorLink: High

MirrorLink use the most modern tools and knowledge to build the software and hardware accepted by the Consortium. Also a revision and approval process is execute after send the software from the Consortium to validate that the developments follow the rules specified in the documents provided to all partners.

Safety MirrorLink: Medium

MirrorLink Consortium indicates that all software and hardware can be build to avoid the driver distractions. In this moment the documents provided by the Consortium recommend that all software and hardware can be accessed by voice commands an also by the controls integrated in the car. But this is not enough to ensure that the driver is not distracted.

Efficiency (usability and performance) MirrorLink: High

For the development of software and hardware from MirrorLink is required to follow the rules indicates by the Consortium in their documents. In this documents one of main requirements is build software and hardware easy to use and also that can use the minor resources possible of the car to execute all task required by the software developed. Also into validation process this requirement is validated and tested and if the product not follow the rules the Consortium request the partner applied the necessary changes to meet the quality requirements.

Maintenance MirrorLink: Medium

All issues and changes in the software and hardware can be validated by the Consortium before the approval and this process may delay the update of the software or hardware with problems.

Usability MirrorLink: Medium

The software and hardware developed by partners of MirrorLink have a good usability but the applications in some cases is complicate to know all available option, this is because the partners developed the software with the old concepts of infotainment systems.

Closeness to market MirrorLink: Low effort

Thanks to large number of partners that participate in the Consortium MirrorLink is being used in a significant number of car brands that have their products place in the market and have a good acceptance by the customers.

More information available [6]

4.5.2 CarPlay

Figure 16: Sample screens of CarPlay

'CarPlay (previously announced as iOS in the Car) is a new standard Apple Inc. introduced for its iOS devices to be able to work with manufacturers' built-in in-car systems. CarPlay is available for all iPhones that use the Lightning connector and operate iOS 7.1 or later'. [7]

CarPlay is the answer of Apple to different connected car solutions. Apple defines their standard and the rules that can be applied to connect the car between mobile devices. One main drawback of this technology is the limitation to Apple ecosystem.

Main features:

- Integrated with Apple devices that are compatible with lightning connector iPhone (5, 5S, or 5C).
- Best user experience based in Apple vision.
- Works with all car controls and Siri Apple voice system.
- Limited number of partners, only the companies selected by Apple can develop software for CarPlay.
- Limited number of OEM companies (currently, only Ferrari, Honda, Hyundai, Mercedes and Volvo). In the future, the list can increase by new companies as BMW, Peugeot, Opel and others.
- Not specifications about API or rules to develop program.
- Closed develop and proprietary program.

Assessment of the technology

Implementation of the solution CarPlay: Difficult

In this moment CarPlay not have any public documentation to implements this system by third parties. Only the companies selected by Apple can participate in the development of software for this system.

Interoperability between different car makers CarPlay: Difficult

As all documents is private and only available for the partners selected by Apple we not have information to know if is easy the interoperability between car makers.

Cost of the ICT tools CarPlay: Medium

Based in mobile experience the developer program haves an annual fee to pay of 99 for small companies and indie developers. For enterprise development the cost is 299 annual. If Apple follows the same strategy for CarPlay similar fees can be applied in the development program. At this moment Apple not has published any document about this information.

Security CarPlay: High

Based in mobile experience, Apple defines the rules that the developers must follow to build valid software to publish in Apple Markets. Also Apple haves a validation process to check that the developer follow the rules indicate in the documents that Apple provides to build software for their platforms.

Safety CarPlay: Medium

Apple applies the same solutions of MirrorLink Consortium and also has the same advantages and disadvantages.

Efficiency (usability and performance) CarPlay: High

With the experience acquired after development mobile devices and software for these devices during 7 years Apple provided a lot of information to build software that have a best efficiency in their devices. Also in the software validation process Apple checks that the software follow all recommendations and rules defined in the documents that provide to software development.

Maintenance CarPlay: Medium

Based in mobile experience Apple have a validation process that required follow several rules to update or fixed problems in the software published in their markets. As same MirrorLink this process may delay the update of the software.

Usability CarPlay: Easy

The experience gained through the development of mobile applications this last 7 years, allows Apple create a very big experience in the usability concept, because this is the main rule to create software for Apple markets

Closeness to market CarPlay: Low effort

Apple is well known in the main markets to place their products with a high penetration for the expectation that creates when creating a new product to market.

More information available at [8]

4.5.3 Open Automotive Alliance

Figure 17: Sample screens of Open Automotive Alliance innitiative

The Open Automotive Alliance is a global alliance of technology and auto industry leaders committed to bring the Android platform to cars, starting in 2014 and promoted by Google.

This is the proposal of Google and other Android companies to response at Apple CarPlay system to port the Android experience from automotive world.

The members of this Alliance include Audi, GM, Google, Honda, Hunday and Nvidia.

Main features:

- A global Partnership: The members of the Open Automotive Alliance share a vision for the connected car, and are committed to collaborate around a common platform to make this vision a reality
- Accelerating innovation in the car: this alliance is created to accelerate innovation in the car with an approach that offers openness, customization and scale. They believe that a common platform will help drive innovation, and make technology in the car safer and more intuitive for everyone.
- An open ecosystem for the open road: this open development model and common platform will allow OEMs to more easily bring cutting-edge technology to their drivers, and create new opportunities for developers to deliver powerful experiences for drivers and passengers in a safe and scalable way.
- No public API defined.
- It is only a proposal and no roadmap plans have been published; only the members of the alliance know the real plan about this proposal.

Assessment of the technology

Implementation of the solution Open Alliance: Difficult

The documentation and details for implement solutions for Open Alliance systems is only available for partners that participate in the alliance. The documentation is not public in this moment.

Interoperability between different car makers Open Alliance: Medium

In this case, Google indicate that all information to interoperability between car makers will be available when the first release of development tools is available and the main effort is that the interoperability be the best possible.

Cost of the ICT tools Open Alliance: Low

Same as Apple, based in mobile experience Google applies a fee of 25$ for the developer program. This fee only is pay one time and provided access from all documents and tools that Google and partners develops.

Security Open Alliance: High

Also as CarPlay, based in mobile experience Google provides the tools and documents required to build secure software for their platforms. The validation process of Google is not as rigid as Apple and in last months in Google Market we can discover malware, but Google is working to fix this problem with the creation of new rules to upload software and also creating a automatic system to detect and delete malware in their markets.

Safety Open Alliance: Medium

Google applies the same solutions of MirrorLink Consortium and also has the same advantages and disadvantages

Efficiency (usability and performance) Open Alliance: High

Google have the same experience in mobile development as Apple and have created many rules and recommendations that the developers must follow to build a valid applications to Google environments. Also in the validation process Google checks that the developers applied this rules.

Maintenance Open Alliance: Medium

Based in mobile experience and same as Apple, Google have a validation process that required follow several rules to update or fixed problems in the software published in their markets. This process may delay the update of the software.

Usability Open Alliance: Easy

As an Apple, with the experience gained this years during the mobile development applications allows Google create a very good experience in usability concept. The feedback provided by the developers and partners allows Google increase the usability experience.

Closeness to market Open Alliance: Low effort

Same as Apple, with their marketing campaigns and the quality of their products, allows Google distributed for fast all of their products with a competitive price.
More information available at [9]

4.5.4 Summary Assessment for Car Connected and HMI Technologies

Table 16: Summary assessment table of car connection solutions and HMI technologies

	MirrorLink	CarPlay	Open Alliance
Implementation of the solution	Medium	Difficult (not info available)	Difficult (not info available)
Interoperability between different solution providers	Easy	Difficult (limited partner members)	Medium (solution can be open and adaptable)
Cost of the ICT tools	Low	Medium	Low
Security	High	High (based in mobile experience)	High (based in mobile experience)
Safety	Medium	Medium	Medium
Efficiency (usability and performance)	High	High	High
Maintenance	Medium	Medium (based in mobile experience)	Medium (based in mobile experience)
Usability	Medium	Easy (based in mobile experience)	Easy (based in mobile experience)
Closeness to market	Low effort	Low effort (based in mobile experience)	Low effort (based in mobile experience)
Overall assessment	**Suitable for FABRIC**	**Suitable for FABRIC**	**Suitable for FABRIC**

Please, refer to 8 ANNEX II: Other car connection solutions for additional technologies that have been considered, but not been included in the analysis because of their limited scope.

4.6 Charging infrastructure operator: Load Balancing Control

The fleet of vehicles connecting to the grid will un-doubtfully pose an additional load to the power grid. Very high saturations or coincidental charging behaviours could result in loads beyond what current grid design can reliably serve. Thus investments in the power generation and distribution system will be required.

In order to provide guaranteed power delivery with respect to Electric Vehicle requirements and constraints related to the secure operation of the grid, it is necessary a module which accounts for electric vehicle limitations, demands and grid inputs (such as the forecasted power supply and price) and calculates a compliant power schedule for vehicles connected to the grid. Such a module is referred to as load balancing module in FABRIC.

In this section it is described a feasibility assessment of implementing such a module within FABRIC.

4.6.1 Introduction to Electric Vehicle load balancing

EV charging load balancing, essentially aims at limiting peak demand on the grid caused by coincidental charging, through manipulating controllable power loads, with techniques such as load shifting and valley filling. Well-balanced power demand and supply, is essential in sustaining the power system's quality. Therefore integration of nonlinear distributed resources such as Electric Vehicles in the electric grid, not only requires an electric connection to it, but additionally needs mechanisms to ensure grid stability. Load balancing ensures grid reliability and additionally can minimize energy cost or indicators of power quality such as the peak to average ratio. In literature it exists two basic approaches for Load Balancing implementation; the centralized and decentralized one.

In the first approach the Load Balancing module requires information such as available power supply, the demand due to Electric Vehicles currently charging, and EV-specific charging parameters that indicate the characteristics of each charging session. The basic outcome of load balancing is a consolidated charging profile that shapes charging session demand in a manner that respects both Electric Vehicle charging preferences and grid operator-imposed constraints. Moreover, as the load balancing module must handle incoming charging requests and monitor the status of charging sessions it could act as a proxy for charging authorization and payment information forwarding. A high level diagram depicting the main inputs and outputs of the module is presented in the following diagram.

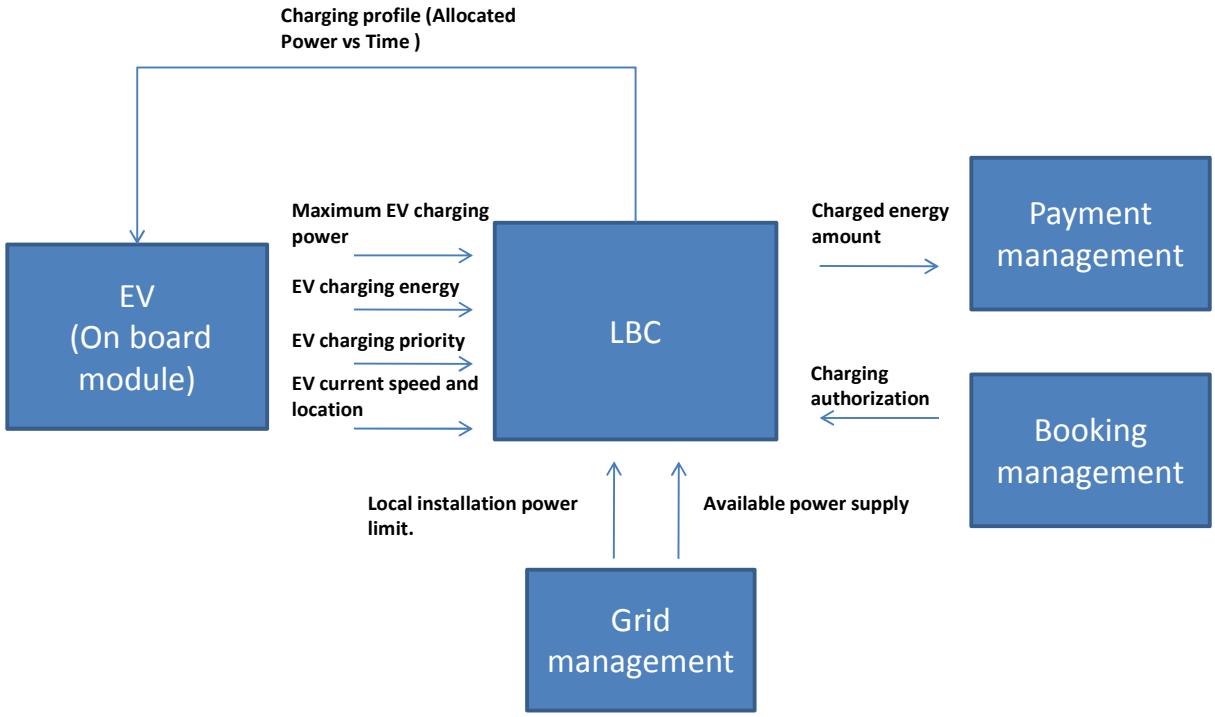

Figure 18: Load balancing module basic inputs-outputs (centralized approach)

In decentralized load balancing, demand scheduling is performed by end users such as the vehicle itself or a charging agent, in response to a global price signal that is transmitted by the grid operator. In decentralized architectures, load balancing algorithms are designed in a manner that ensures both user and system optimality. The following diagram summarizes the architecture

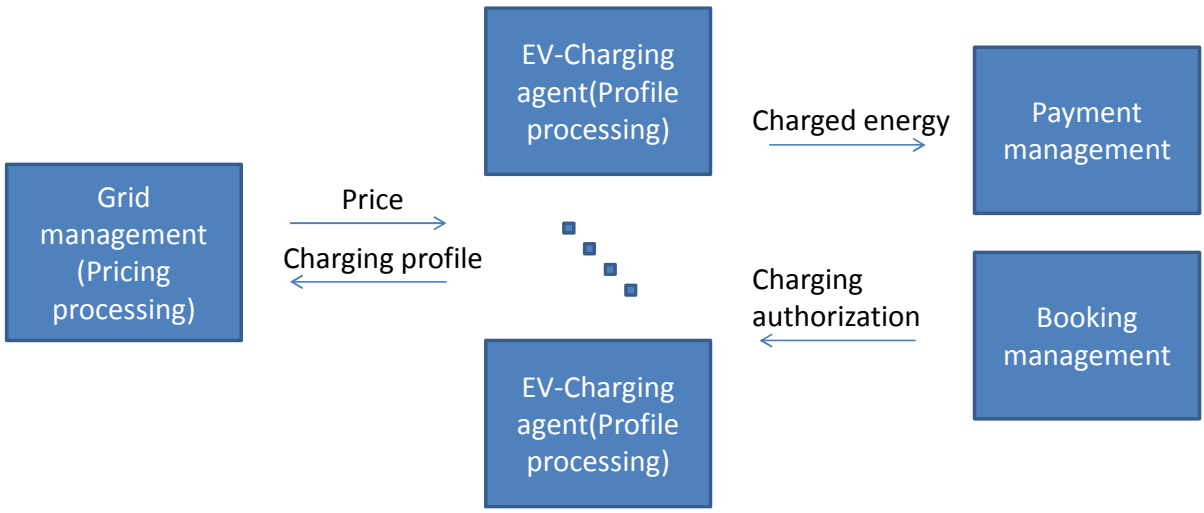

Figure 19: Load balancing module basic inputs-outputs (decentralized approach)

Within FABRIC, static, stationary and dynamic wireless charging modes will be supported. Therefore load balancing implementation specifics may differ per charging mode.

One major difference among static and dynamic modes is the duration of the charging procedure. In static charging, slow charging (up to 8 hours) is currently the norm, which provides more flexibility in performing load shifting and valley filling. Moreover there are no hard time constraints that restrict the load balancing module's response time as long as the produced charging schedule is optimal in terms of power supply utilization. In this case, and when considering the centralized approach, a large amount of charging spots can be aggregated to the centralized load balancing module that handles the overall charging management. In the dynamic on-road charging scenario, charging duration timescale is within seconds to minutes at the most, depending on the charging lane's length and the speed of the EV during charging. Therefore the load balancing module should exhibit, deterministic behaviour and bounded processing duration in order to provide near real-time charging schedules (profiles) to EVs. This difference is expected to have a major impact on the design and requirements of the system's modules.

For additional input on Load Balancing technologies description, please, refer to ANNEX I: Load Balancing in Electric Vehicles charging solutions

4.6.2 Technical feasibility within FABRIC of the Load balancing Module

Ongoing feasibility studies within FABRIC and recommendations

An assessment of the current ICT and charging solutions is being performed within WP23, WP33. In order to meet feasibility requirements, a link should be established with the technical benchmarking tasks in order to ensure that the selected charging equipment and protocols enable real time load balancing, especially within the dynamic wireless charging environment. Some of the parameters that could be taken into account during this assessment of communication technologies are as follows:

- High layer message transversal time (OSI layer 7-4)
- MAC layer transmission delay
- Physical channel propagation delay

Moreover the communication protocols to be assessed should be based on direct point to point or bus technologies that use deterministic medium control access.

In addition to the communication channel investigation an assessment of the execution platform with respect to real time behaviour must also be performed. Especially in the case of dynamic wireless charging, that may last as much as 2-3 seconds, immediate response with minimal guaranteed latency is essential.

The Operating System to be used within FABRIC should be characterized with respect to the following attributes.

- Real time task scheduler

- Support for task pre-emption based on priority
- Bounded task switching latency
- Real time message queue support for inter-task communications

Within FABRIC the following or similar platforms could be assessed: RT-Linux, Linux-RTAI, RTEMS.

In order to test the real time behaviour of the load balancing module it is advisable to execute off-line simulations that take into consideration the types of events (periodic or aperiodic) that would occur during the operation of the platform along with some of the basic characteristics of the execution platform such as the scheduler of the Operating System and evaluate the overall response time of the solution.

Harmonization with charging related protocols and standards

An essential requirement in the design and development of the FABRIC system is to comply with smart grid and vehicle charging communication protocols. The use of standardized interfaces is essential in promoting a harmonized design, therefore standardized protocols such as DLMS/COSEM 62056 , ISO/IEC 61850 and electric vehicle charging protocols that have already been developed for conductive charging systems such as ISO/IEC 15118 will be considered and evaluated with respect to their suitability and applicability in the wireless charging domain. Moreover the FABRIC consortium is represented in the ISO/IEC JPT 19363 "Electrically propelled road vehicle – Wireless power transfer for charging" working group and will provide technical input regarding the harmonization of communication requirements with respect to real time load balancing.

Assessment of the technology

Implementation of the solution: Difficult

The implementation of the system can be based on existing load balancing solutions developed in the PowerUp project or other approaches presented in the previous chapter. However adaptation of existing solutions with respect to communication interfaces will be required according to the finalized architecture of the FABRIC system. Moreover the FABRIC implementation will have to take hard real time constrains, present in dynamic charging environments into consideration. (Not considered in PowerUp)

Interoperability between different car makers: Difficult

Interoperability between different car makers depends on the deployment of a harmonized communication protocol used for inductive charging. Lack of standardization in this particular domain makes interoperability very difficult

Cost of the ICT tool: Medium

The actual cost of the SW libraries and interfaces used to build the system could be low. However depending on the finalized architecture of the solution, specific communication module HW/SW may need to be acquired and may increase the total cost.

Security: Low

Current methodologies do not take communications security into consideration therefore the Load Balancing module is vulnerable to threats that could occur from unauthorized load balancing requests. Additional development effort is required in order to establish a secure connection between the LBC and client devices.

Safety: Medium

Existing LBC's have been tested and simulated in small scale deployments or simulation environments. Therefore exhaustive testing must be performed in order to certify the safe operation of the LBC.

Efficiency: High

Deployment of such a solution will support guaranteed power delivery with respect to Electric Vehicle requirements and constraints related to the secure operation of the grid.

Maintenance: Medium effort

The load balancing control may require to be updated according to developments in standardization regarding interfacing with smart meter systems or charging control equipment. However due to the fact that most standards are backwards compatible maintenance will not be frequently required

Usability: Easy

The load balancing module will execute automatically. Therefore no human intervention is required

Closeness to market: High effort to market

Standardized interfaces for the load balancing module have not been proposed yet. Therefore any solution proposed will be based on a custom interface or interfaces that seem to be emerging from current standardization activities.

Load balancing is a technology that enables demand side management thus eases efficient use of energy, on the basis of flexible loads such as electric vehicles. However it is not only essential in reducing the energy cost, it additionally ensures that charging operations are performed in a controlled manner. The core aspects of this technology have been analysed in

literature and other electro mobility projects so existing methodologies will assist the development of such a module. Therefore the Load Balancing is suitable for FABRIC.

4.6.3 Summary Assessment for implementing Load Balancing Control

The assessment of the implementation of the load balancing module is summarized in Table 17. Each indicator can be characterized by an assignment grade. The rationale of the proposed grading is explained in detail as follows.

Table 17: Assessment table for Load Balancing

	Assessment grade
Implementation of the solution	Difficult
Interoperability between different solution providers	Difficult
Cost of the ICT tools	Medium
Security	Low
Safety	Medium
Efficiency (usability and performance)	High
Maintenance	Medium effort
Usability	Easy
Closeness to market	High effort
Overall assessment	**Suitable for FABRIC**

4.7 Infrastructure charging control

This section shows two possible ICT solutions for vehicle access to the FABRIC system, considering its communication with the charge infrastructure. The basic solution is the ISO/IEC 15118, and also shows the solution being developed within the European project UNPLUGGED.

4.7.1 Access/Charging management: ISO/IEC 15118 protocol

ISO/IEC 15118 is a standard that defines a communication protocol between electric vehicles (EV) and the electrical supply equipment (EVSE). There are communication parts in both equipment, the electric vehicle communication controller (EVCC) and the supply equipment communication controller (SECC). This normative is oriented to electric road vehicles, but is not a closed protocol, and it can be used for other vehicles as well. ISO/IEC 15118 describes all the aspects involved in the charging process, including actors, the different use cases and the communication in all layers of the Open Systems Interconnection (OSI) reference model.

About the actors, there are two kinds, primary and secondary actors. Primary actors are those that are directly involved in the charging process, like EVCC and SECC. Those that are not directly involved are secondary actors, like the energy provider.

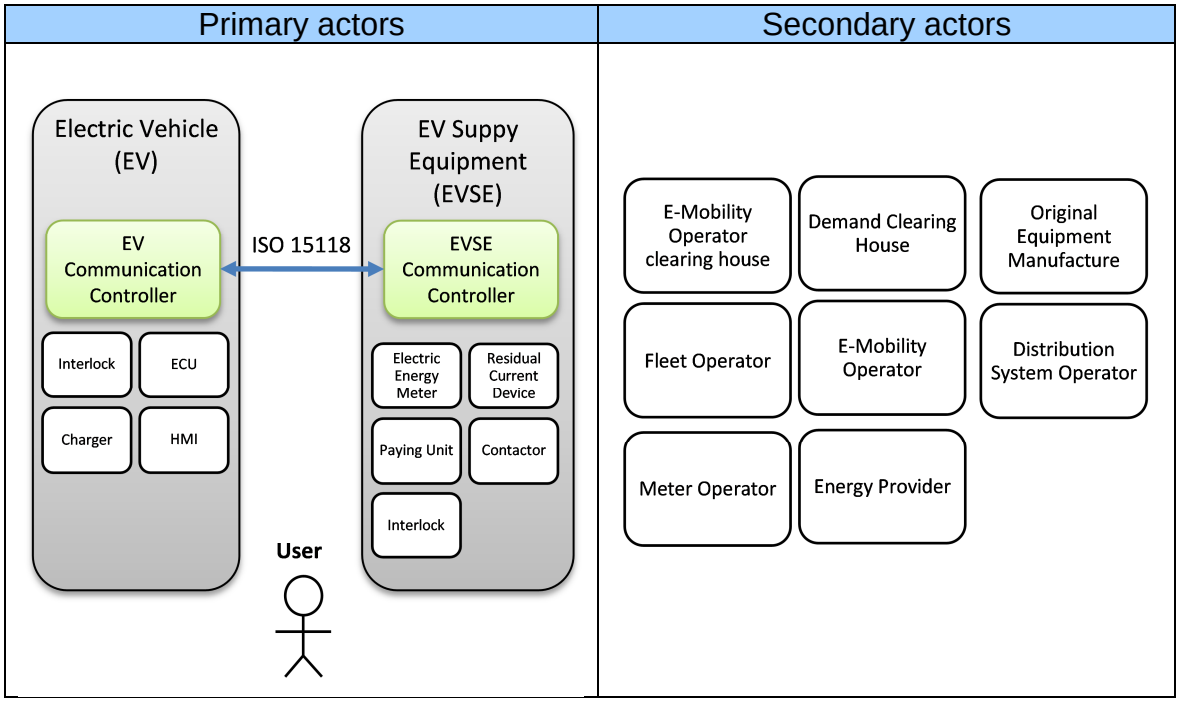

Figure 20: Primary and secondary actors in the ISO/IEC 15118

The communication protocol involves all the layers of the OSI model. In the physical layer a PLC signal is used to detect if the car is connected and if it is ready to charge. Network and

transport layers will use the standards protocols IPv6 and TCP/UDP to establish the high level connection. In the higher layers the Vehicle to Grid Transfer Protocol (V2GTP) is implemented.

V2GTP messages are transmitted using XML format. To guarantee the security of the transmission, the message is passed by Efficient XML Interchange (EXI). EXI protocol codifies the XML message to a series of bits. This process reduces the size of the message and prevents external reading of the message because the XML is readable for humans.

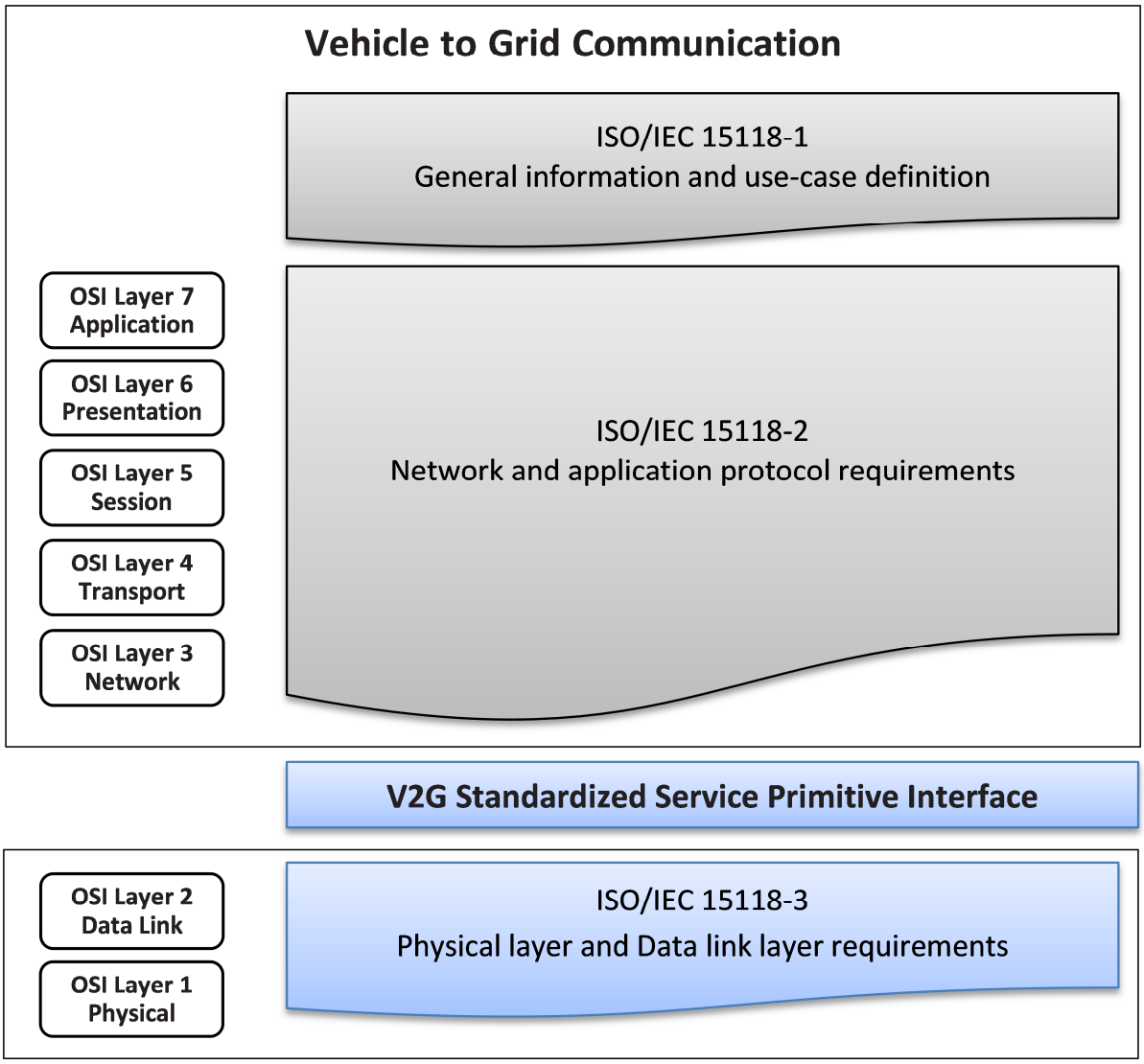

Figure 21: ISO/IEC 15118 protocol layers

The communication architecture of the system is thought as client/server architecture. The EVCC is the client and the SECC is the server. That means that the vehicle makes the requests and the station responds with the requested information.

The charging flux starts with an exchange of general information like the IDs of the vehicle and the station. After that a *handshaking* process starts to stablish the type of charge, way of

payment, additional services and other general information. In this process there is also a negotiation of the initial charging parameters. When these parameters are fixed and the station has validated that the vehicle is allowed to charge, the charge process could start. During the charge there is an exchange of messages to control if there is some problem during the process. If there is some error, the charge is stopped as fast as the electronic is able to avoid unsafety situations. Once the vehicle has been fully charged, the process is ended and another charge could start immediately.

Summarizing the characteristics of the ISO/IEC 15118, this protocol has a lot of potential in the future. It allows not only the charge of EV, also it will be possible to add value services as downloading information from Internet. It has high security, as much in the message transmission with the EXI protocol, as the use of authentication and certificates to identify the vehicle and allow or not the charging process. Charging protocols are exclusive; it means that a CHADeMO vehicle cannot charge with an IEC 15118 station. It is a relative new protocol, so there will be not many vehicles with this protocol implemented, but in the future it is thought to be a worldwide standard. It is not a closed protocol, so in the future there will be changes. It cannot be assured that new versions of the protocol will work fine with the oldest ones, so maintenance must be taken into account.

Assessment of the technology

Implementation of the solution: Difficult

This protocol demands a development involving all the layers of the OSI model, using different protocols in each layer. That means we have to make a development for every layer. Apart from the communication with the vehicle, the charger has to develop a charging manager that controls the charge and the possible errors that could occur. This normative has a lot of restrictions about time delays and behaviours of the actors during the charge. Definitely, it is a well enclosed protocol, but this complete control of the charge reflects in an important work to fulfil all the specifications.

Interoperability between different solution providers: Difficult

As pointed in the description of the protocol, each charging protocol is exclusive, it is impossible to charge a vehicle that implements the IEC 15118 without a charger with the same protocol. It is not really a problem because each charging protocol has the same problem. As this protocol is thought to be the worldwide standard, in the next years this problem will not be relevant.

Cost of the solution: Medium

The development of the charging protocol is mostly software. That means the major costs are from the working hours of the developers. There could be some hardware cost for measurement

devices in case the charger does not include them for its own control. Compared with other charging protocols, the cost will not be really increased.

Security: Medium

The problem of transmitting information using XML is that it is readable by humans, but it is solved using EXI encryption. This encryption prevents reading the information instantly. However, if the intruder has access to the specification of the protocol, he could be able to obtain the original XML.

Safety: High

The extension of the protocol provides coverage for a lot of behaviours and errors of the charge and the vehicle. That means that is really difficult that charging a vehicle could bring to an unsafety situation.

Efficiency: High

If we understand efficiency as the amount of resources needed for the operation of this protocol, compared with other possibilities, it needs more resources, but the possibility of having a thorough control and added value services makes it worth it. Besides, the additional resources needed do not suppose a higher cost, just more computing capacity from the processor.

Maintenance: High

One of the main problems of the charging protocols is that the version of the protocol of both primary actors has to be the same because otherwise, the charging is not allowed. That means that the charger has to be updated to the latest version of the protocol and has to maintain the previous versions to provide support to all the possible versions of the protocol. In case of software changes, it is not very demanding, but when there are some changes in the electrical specifications to more restrictive ones, it is a problem that has to be solved fast.

Usability: Medium

The charging protocol is out of sight from the user, so here we are talking about usability from the point of view of the developer of the protocol. The developing of this normative is quite extensive, but it is not really difficult to understand. The messages are defined using XML, which is easy to read. Apart from that, all the flow of the charge is very well defined so it can be completely understood. The definition of a wide amount of restrictions leaves few doubts about the implementation of the features to the developer.

Closeness to the market: Medium

Nowadays the market is demanding CHADeMO chargers mostly, and it will take some years until this protocol monopolizes it. But some of the most important manufacturers of the self-propulsion sector are involved in the development of a final specification of the IEC 15118.

According to the points previously described, this protocol would be **suitable for FABRIC** once it is adapted to wireless charge, as described in the following section for the Unplugged Project.

4.7.2 Access/Charging management: Unplugged Project protocol

Nowadays there are several projects developing communications for inductive systems. One example of these projects is the European project Unplugged, which attempts to investigate and develop inductive charging systems for electrical vehicles in urban environments. The development of the communication protocol in that case is in charge of Continental and CIRCE mainly. The proposed solution is an adaptation of the international standard for conductive charging IEC 15118, previously described. Figure 22: Scheme of the Unplugged charging system shows a schematic of the system delivered in Unplugged. The communication itself is performed by the EVCC (Electric Vehicle Communication Controller) and SECC (Service Station Communication Controller). When the communication is stablished, the charger includes the typical power electronics included in conductive chargers and the charging circuit involves the specific power electronics for the inductive charging.

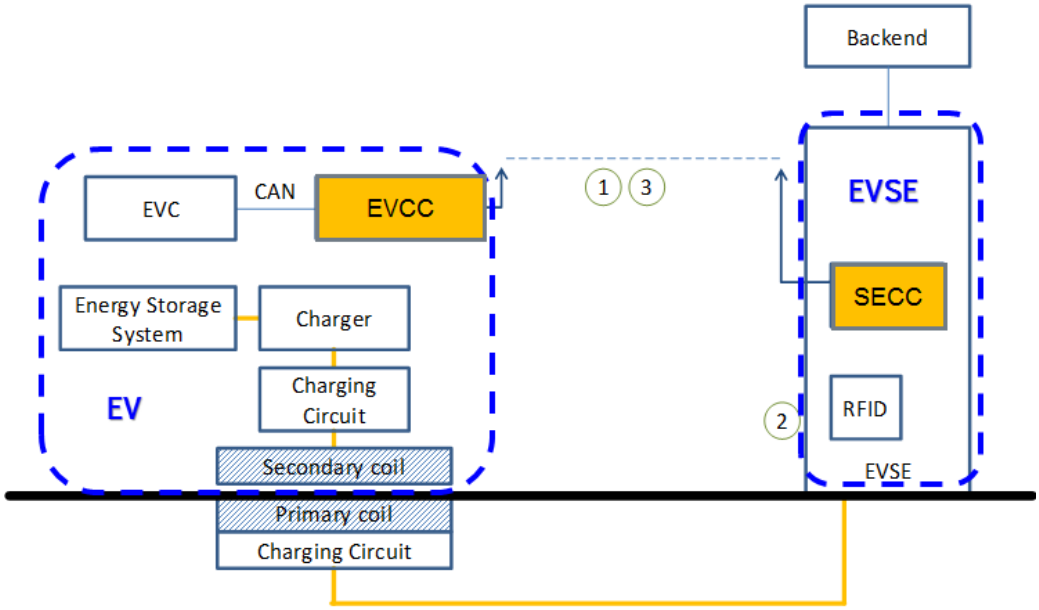

Figure 22: Scheme of the Unplugged charging system

To perform the communication between vehicle and station, a Wifi router has been included in both systems. The communication starts as soon as the vehicle enters in the Wifi action radio. The connection with the Wifi net is automatic. The first protocol messages exchange general information like the IDs of the vehicle and the station. After that a handshaking process starts to stablish the type of charge, way of payment and other general information. In this process there

is also a negotiation of the initial charging parameters. When these parameters are fixed and the station has validated that the vehicle is allowed to charge, the charge process could start. During the charge there is an exchange of messages to control if there is some problem during the process. If there is some error, the charge is stopped as fast as the electronic is able to avoid unsafety situations. Once the vehicle has fully charged, the process is ended and another charge could start immediately.

The authentication of the vehicle is carried out using a RFID card. The identifier is send to the energy dealer by the station to validate or not the charge. The energy dealer should have a white list where the vehicle has to appear. The definition of the vehicle and station identifiers adjusts to the format of the e-Mobility Account Identifier (EMAID). The intention is to stablish this format as standard in the future.

To interact with the user, there is a touch screen in the station that shows information about the state of charge and the events that could happen during it, like errors.

Assessment of the technology

Implementation of the solution: Medium

The implementation of the protocol is similar to the ISO/IEC 15118 standard described above, but the UNPLUGGED protocol is easier to implement as it is simplified and adapted specifically for inductive power transfer. The implementation of the UNPLUGGED protocol is easier because some of the characteristics of the standard normative have been discarded because they are not necessary in this specific case.

Interoperability between different solution providers: Difficult

The same issues are present as in the ISO/IEC 15118 standard.

Cost of the solution: Medium

The same costs are expected as for the ISO/IEC 15118 standard.

Security: High

The security is higher because XML messages are eliminated and the communication is performed using CAN messages. The advantage of using CAN is that the definitions of the messages are not standard and it is nearly impossible to decipher the information.

Safety: Medium/High

The safety could be reduced slightly because some timeouts and safety measurements of the standard are not included in this implementation and that could lead to some behaviours of FABRIC not present in Unplugged.

Efficiency: High

The same or even higher efficiency is expected as for the ISO/IEC 15118 standard.

Maintenance: Medium/High

The assessment of maintenance is rather uncertain because, as being a specific protocol, the only changes will be done by the partners of the project rather than by the developers of the normative. The maintenance then will depend on the quantity of changes included in the future, but probably it will be lower than the standard.

Usability: Medium

The same usability is expected as for the ISO/IEC 15118 standard.

Closeness to the market: Medium

The closeness to the market will be lower because this solution has been developed for this particular project and market readiness is still to be confirmed.

4.7.3 Assessment summary of access/charging management protocols

To summarize the differences between the ISO/IEC 15118 and Unplugged, both protocols assessments are shown in the following table and a further explanation is presented after this table.

Table 18: Summary of the assessment of ISO/IEC 15118 and Unplugged protocols.

	ISO/IEC 15118	UNPLUGGED
Implementation of the solution	Difficult	Medium
Interoperability between different solution providers	Difficult	Difficult
Cost of the ICT tools	Medium	Medium
Security	Medium	High
Safety	High	Medium/High
Efficiency (usability and performance)	High	High
Maintenance	High	Variable

Usability	Medium	Medium
Closeness to market	Medium	Low
Overall assessment	**Suitable for FABRIC**	**Suitable for FABRIC**

It should be mentioned here that although both protocols (ISO/IEC 15118 and UNPLUGGED) are suitable for FABRIC, they cannot be applied directly and modifications will be necessary. As the protocol developed in the UNPLUGGED project includes specific variations of the ISO/IEC standard in order to adapt it for inductive power transfer, this solution may need less modifications than the original standard, which was designed for conductive power transfer.

4.8 Charging Assistance

During the dynamic wireless power transfer the lane alignment (active lane keeping) could be automatically adapted via the driver assistant systems in order to optimize the efficiency rate of the energy transfer and to synchronize the energy transfer via the coil systems as needed and adjusted to the charging infrastructure.

4.8.1 Active Lane Keeping Assist technology

The vehicle should be equipped with a positioning system (DGPS or Magnetic positioning sensors) and a position control system (Actuator) that follows a nominal trajectory pre-defined. The system could control the steering angle in order to follow the predetermined trajectory, while the driver will control the speed of the vehicle through the accelerator pedal and brake pedal. During the docking process, position sensors first detect vehicle's lateral deviation from the lane center. The vehicle‘s lateral deviation is then fed back to vehicle ECU, where the corresponding steering command will be calculated and sent to a steering actuator. The steering actuator will be activated according to the received command and maintain the vehicle within the maximum allowed deviation.

In principle, design of steering actuator is extremely similar for different existing electronic automatic control technologies, while an electric motor is usually used to actuate the bus steering system. Thus, automatic control technologies can be distinguished by their method of determining the vehicle's lateral deviation from lane center.

4.8.1.1 Magnetic guidance system

In Magnetic guidance systems, magnetic material (e.g., magnetic tape or discrete magnets) are used, either located on, or embedded in, the center of the lane.

Magnetometers mounted under the vehicle first estimate the strength of the magnetic field when the vehicle passes over the magnetic material (e.g., magnetic tape or discrete magnets). Then, based on the magnetic field strength and the magnetic field characteristics of the magnet, onboard signal processing software can calculate the relative deviation from the vehicle to the magnet, consequently the position of vehicle is determined.

Moreover, magnetic guidance system is the only verified technology with the capability to be operated under all weather and operation until now.

The advantages and disadvantages of magnetic guidance system are listed below:

Advantages

- Low sensitivity to environmental factors such as climate, darkness and pavement conditions.
- Positioning accuracy is quite high, which can reach as high as centimeters.
- Binary coding is possible for this system (e.g., road curvature or kilometer post)

Disadvantages

- Plenty of ferrous components present in the vehicle, such as structural supports or reinforcing rods, may distort the magnitude of local magnetic field. This distortion can lower the performance level of lateral sensing and accuracy.
- Noise effect on lateral measurement may occur if the magnetic marker installation is not good enough, for instance, too close or too deep to the road surface, or not perpendicular to the road surface.
- Since the field strength of magnets is relatively low, the maximum range the lateral position can be reliably estimated is restricted.[7]

4.8.1.2 Vision based guidance system

In vision-based guidance systems, information is extracted from images captured by cameras, the systems "look" for specific lane attributes and determine the lateral position of a vehicle based on its relative position to the identified lane markers.

Some systems have been designed to operate on unstructured roads which means, running without any identified lane markers.

Advantages:

- Fewer infrastructure modifications are required for vision based guidance controls.
- Vision information not only contains identify markers, but also road curvature, slop, etc.., consequently this system is foreseen to facilitate in the future. Moreover, traffic sign recognition and obstacle identification can be anticipated.
- Vision-based sensors don't alter or impact the environment. Hence minimize the chance of sensor interference with other systems both on and off the vehicles.

Disadvantages:

- High sensitivity to environmental factors such as climate, darkness and pavement conditions.
- High maintenance cost, too expensive to periodically repaint the lane markers.

4.8.1.3 DGPS based guidance system

The Global Positioning System (GPS) is a convenient and accurate method for determining vehicle position in a global coordinate system with a quite low infrastructure cost. Differential Global Positioning System (DGPS) is an enhancement to GPS that provides improved location accuracy, from the roughly 10 meter nominal GPS accuracy to centimeter level in case of the best implementations.

DGPS uses a network of fixed, ground-based reference stations to broadcast the difference between the positions indicated by the satellite systems and the known fixed positions. These

[7] Not applicable for Inductive dynamic wireless power transfer.

stations broadcast the difference between the measured satellite pseudo ranges and actual (internally computed) pseudo ranges, and receiver stations may correct their pseudo ranges by the same amount. The digital correction signal is typically broadcast locally over ground-based transmitters of shorter range.

Advantages:

- Infrastructure cost is quite low compare with all other technologies.
- With digital maps, path preview and roadway information can also be captured in advance, this information can be used to facilitate electronic guidance design and help the driver to determine the optimal path.
- GPS signals are available in all weather conditions.
- Unlimited sensor range.

Disadvantages:

- Though GPS signals can be broadcast under all weather conditions, environment does affect GPS position accuracy. DGPS requires a clear view of a substantial portion of the sky above to receive signal from the satellites overhead.
- Large transient error may occur when the number of satellites received by GPS changes.
- GPS has some characteristics which may complicate the control system design for electronic guidance functions, for instance, relatively low update rate (< 20 Hz), significant latency.
- GPS antenna is usually installed on top of the vehicle, which is generally far away from the vehicle's center of gravity (COG), hence creating strong coupling between GPS estimate and vehicle roll or pitch motions.

4.8.2 Summary Assessment for Charging Assistance Technologies

Firstly, it is important to highlight that the final assessment cannot be done until the all the wireless charging solutions will be fully tested in SP3 and the complete requirements for the lane keeping system will be available. The accepted vehicle‘s lateral deviation strongly depends on how the wireless charging devices (on road and on board parts) are designed. The main factors that affect the misalignment tolerances are:

- Dimensions of the primary and secondary coils
- Electromagnetic design of the coils
- Effective air gap between the primary and secondary coils

All these factors have to be frozen during the SP3 work and are not available during the preparation of this report.

Table 19: Active Lane Keeping Assist Sensors technology

	Magnetic	Vision based	DGPS based
Implementation of the solution	Difficult	Easy	Medium
Interoperability between different solution providers	N/A	N/A	N/A
Cost of the ICT tools	High	Low	Medium
Security	N/A	N/A	N/A
Safety	High	Medium	Low
Efficiency (usability and performance)	High	Medium	Low
Maintenance	Easy	Difficult	Medium
Usability	N/A	N/A	N/A
Closeness to market	High effort	High effort	Low effort
Overall Assessment	**N/A**	**N/A**	**N/A**

4.9 Payment: Overview of interfaces available

The scope of this section is described and evaluates several Payment Methods to be applied for future electric vehicles.

The focus is to examine payment methods and technologies currently in use in various transportation modes, with reference to Toll Collection solutions that seems to be particularly suited in the context of payment of electric vehicle charging.

The technologies considered in the section represent the state of the art of the toll payment and can be summarized as follows:

- Smart cards in payment
- Electronic Toll Collection
- Mobile payment

4.9.1 Electronic payment systems models

Existing electronic payment systems used in data and telecommunication networks typically follow either a three party or a four party model.

One party is the payer, i.e the consumer who has an account agreement with a financial institution, for example with a bank. Another party is the payee, typically a retailer, who is paid for services or goods delivered to the payer. Whether the model consists of three or four parties depends on the payment provider, which could be either a single financial institution or a network of them.

A very good example for this difference can be observed in the credit card market today:

- The three party model: In this model card payments are handled within single organizations, so the issuer (having the relationship with the cardholder) and the acquirer (having the relationship with the Merchant) is the same entity.
  This means that there is no need for any charges between the issuer and the acquirer. Since it is a franchise setup, there is only one franchisee in each market, which is the incentive in this model. There is no competition within the brand; rather you compete with other brands.
  Examples of this setup are Diners Club, Discover Card, American Express and other closed loop system like restaurant checks.

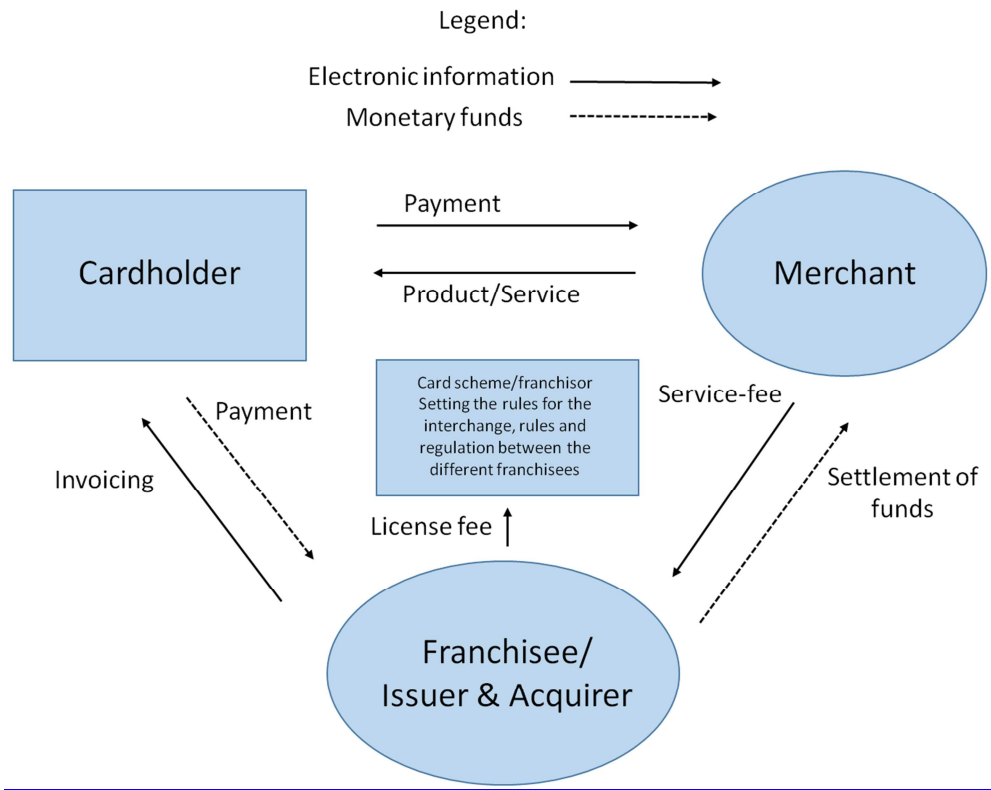

Figure 23: Three party model

- The four party model, i.e. the network of financial institutions, is what we observe e.g. at Visa or MasterCard. Both have a number of member banks, some of them issuing cards, others authorize and acquire the payments for merchants. Typically, there are in addition central operators, who co-ordinate authorizations, captures and clearings.

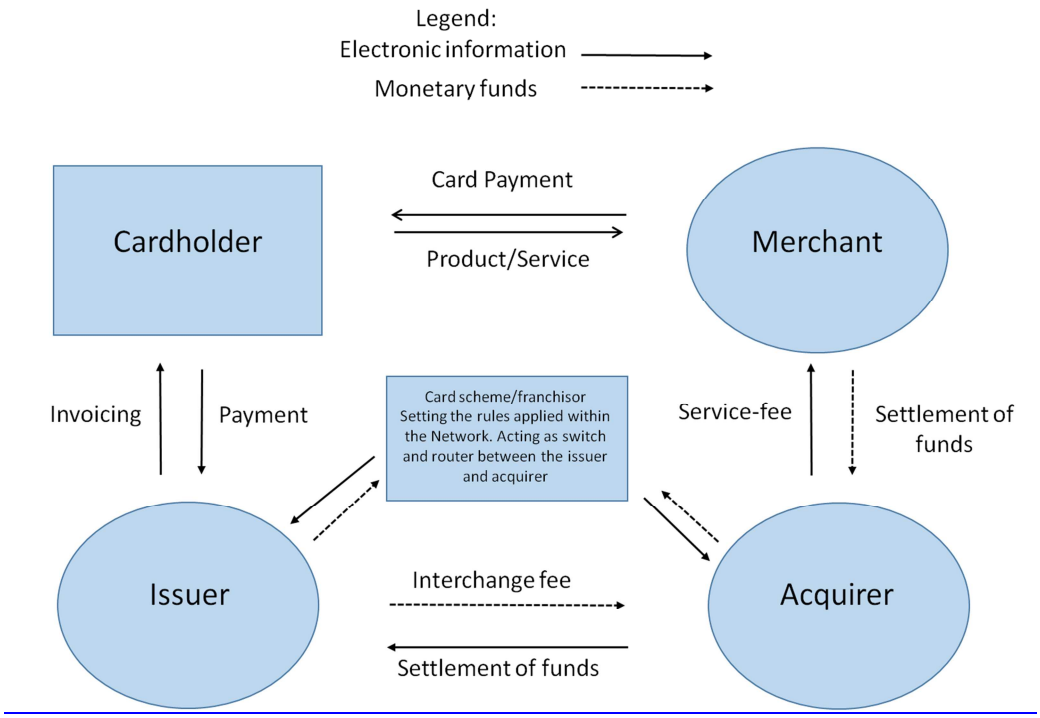

Figure 24: Four party model

4.9.2 Payment technologies from user side

4.9.2.1 Smart cards & credit card

Smart cards are essentially a credit card sized payment card that has a computer chip embedded in its body.

Smart cards are either contact, meaning they must be physically inserted into a reader and contact made between the reader and contacts on the chip, or contactless, where the card must be within 10 cm of the reader to achieve coupling with the reader.

Both variants of smart cards are covered by International Organization for Standardization (ISO) standards (ISO 14443 for contactless cards and ISO 7816 for contact cards).

As the smart card industry has matured, contactless has become the overriding choice for any payment application.

The rationale for the use of smart cards in toll payment mainly had to do with the speed and accuracy that the fare collection system could achieve using a more powerful and secure smart medium with a contactless interface. The toll system has a strict speed requirement for smart card transactions or 300 msec (and 250 msec has been a strong requirement).

Another key factor was the incredible levels of reliability of a smart card system. The card itself is very durable and not subject to degradation like a magnetic card, and the reader (or validator,

in the parlance of the smart card system) is also incredibly reliable with very low levels of maintenance required.

Another side of the card market is the credit card system which is the preferred method of payment for most consumers.

There are two main protocols, which are used to secure online purchases with credit cards: the Secure Socket Layer (SSL) protocol, and the Secure Electronic Transaction (SET™) protocol. However, both protocols have some disadvantages, and therefore other payment systems for credit cards have been developed as well.

Europay, MasterCard, and Visa (EMV) jointly developed specifications, which define a set of requirements to ensure interoperability between integrated circuit cards (smart cards) and terminals on a global basis, regardless of manufacturer, financial institution, or location of card usage. The combination of the card's tamper-resistance with asymmetric (public key) and symmetric (shared key) cryptographic operations allow for a high level of security in EMV card transactions:

- Asymmetric security mechanisms authenticate the smart card as a valid card to the terminal
- Symmetric security mechanisms generate and verify transaction cryptograms (essentially Message Authentication Codes, MACs) based on a key shared between card and issuer.

  Chip Electronic Commerce is a part of the EMV 2000 specification. It defines the use of a smart card application to conduct a credit or debit transaction in an electronic commerce environment using a Secure Electronic Transaction (SET) compliant software. Chip Electronic Commerce combines the EMV functions with the Secure Electronic Transaction specification to provide a protocol for secure smart card based transactions over the Internet. It takes advantage of two enhancements to the SET protocol
- SET Common Chip Extension: extends the SET protocol to support the transport of smart card related data.
- Online PIN extension: extends the SET protocol to support the online transport of a cardholder's PIN.

  In addition, Chip Electronic Commerce extends the SET specification by supporting two key features of EMV smart card applications:
- Online card authentication, through the use of a cryptogram.
- Cardholder verification, through the use of an optional cardholder PIN.

Assessment of the technology

Implementation of the solution: Easy

It is the most used payment system with a standard application and installation

Interoperability between different solution providers: Easy

There is different worldwide standard which cover the entire smart or credit card transaction.

Cost of the solution: Low

The cost it's quite low because there is a strong competition on this market

Security: N/A

Good security of the solution and new improvement on security comes out every day.

Safety: High

Efficiency: High

Maintenance: Easy

Only to change the card if it breaks.

Usability: Easy

Almost any user is used to pay with a card.

Closeness to the market: Low effort

There is a strong completion on this market so almost any solution is easy to find.

4.9.2.2 Mobile payments

The mobile payments sector is an important and strategic industry segment. It is a space that is a convergence of the wireless communications, banking, financial payments and smart card industries.

This sector has within it multiple potential applications; payments—retail and transportation, communications, internet, banking, and others.

The business model is a complex one and standards are still emerging. It is the realm of joint ventures, small internet starts, academia, and others vying to position themselves to partner with wireless carriers, mobile handset manufacturers, and the financial community.

The scenario of a mobile application ecosystem that includes a payment application as well as value-added applications such as loyalty, smart couponing, mobile banking, and, in the case of transportation, ITS applications.

Mobile devices paint a compelling picture of a future, robust system that cannot just innovate transit payments, but perhaps achieve multi-modal transportation payments.

The technological approach that seems to be the way forward is Near Field Communication (NFC).

NFC is a set of standards for smartphones and similar devices to establish radio communication with each other by touching them together or bringing them into proximity, usually no more than a few inches.

Present and anticipated applications include contactless transactions, data exchange, and simplified setup of more complex communications such as Wi-Fi. Communication is also possible between a NFC device and an unpowered NFC chip, called a "tag".

NFC tags contain data and are typically read-only, but may be rewriteable. They can be custom-encoded by their manufacturers or use the specifications provided by the NFC Forum, an industry association charged with promoting the technology and setting key standards. The tags can securely store personal data such as debit and credit card information, loyalty program data, PINs and networking contacts, among other information. Tags currently offer between 96 and 4,096 bytes of memory.

Near-field communication uses magnetic induction between two loop antennas located within each other's near field, effectively forming an air-core transformer.

There are two modes:

- Passive communication mode: The initiator device provides a carrier field and the target device answers by modulating the existing field. In this mode, the target device may draw its operating power from the initiator-provided electromagnetic field, thus making the target device a transponder.
- Active communication mode: Both initiator and target device communicate by alternately generating their own fields. A device deactivates its RF field while it is waiting for data. In this mode, both devices typically have power supplies.
  Extending the capability of contactless card technology, NFC also enables devices to share information at a distance that is less than 4 centimeters with a maximum communication speed of 424 kbps. Users can share business cards, make transactions, access information from a smart poster or provide credentials for access control systems with a simple touch.
  NFC’s bidirectional communication ability is ideal for establishing connections with other technologies by the simplicity of touch.

Figure 25: NFC Applications

Assessment of the technology

Implementation of the solution: Medium

It's easy to install the HW but the SW needs a lot of customization

Interoperability between different solution providers: Difficult

The NFC standard regards the communication level so any provider has developed a proprietary hardware and software.

Cost of the solution: Medium

This technology is spreading now so the cost of this solution is lowering

Security: High

Good security of the reader and the data communication but, the user terminals doesn't match the higher standard of security yet.

Safety: Medium

Efficiency: Medium

Maintenance: Medium

Very few maintenance needed on hardware side but on software side it needs some effort to keep it up and running thought time.

Usability: Medium

The European users are not already used to pay with this technology.

Closeness to the market: Medium effort

This technology is growing in these days so the effort to implement this solution is still quite big.

4.9.2.3 Electronic Toll Collection

ETC systems are currently RFID transponder technology based.

At the heart of these systems is a transponder that is placed in the windshield area of a car and communicates with a reader placed over the toll plaza fee payment area.

Electronic Toll Collection systems were introduced in several European countries in the early 1990s.

The European toll systems are not interoperable and the road users must be equipped with on-board unit (OBU) specific to each country or tolled domain. So the drivers have to affix several electronic tags inside their vehicle in order to take advantage of the various systems encountered on their itinerary.

In view of the growth of international road traffic, the objective to internalize road externalities has gained particular weight and a number of Member States actively consider introducing extensive electronic road toll systems. The interoperability of existing and future systems must be ensured.

The European Electronic Toll Service (EETS) will ensure interoperability of tolling services on the entire European Union road network. EETS will enable road users to easily pay tolls throughout the whole EU with only one subscription contract with one service provider and a single on-board unit. By limiting cash transactions at toll stations and eliminating cumbersome procedures for occasional users, EETS will facilitate daily operations for road users, improve traffic flow and reduce congestion.

The general context of a toll charging environment and the main roles within EETS are shown in the Figures below, taken from draft standard prEN ISO 17573:2010.

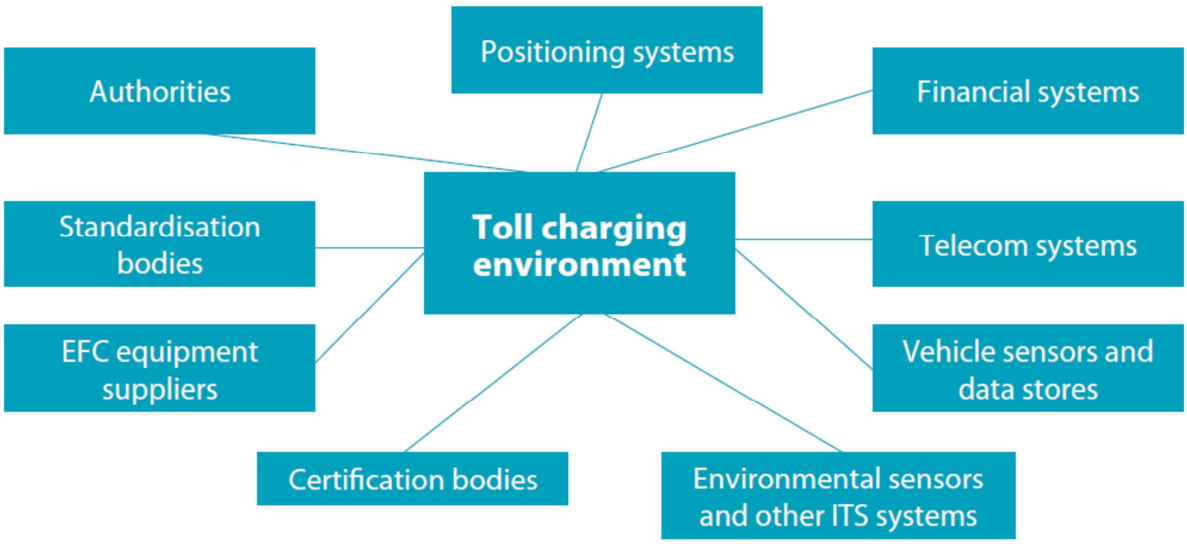

Figure 26: General context surrounding an electronic road toll system

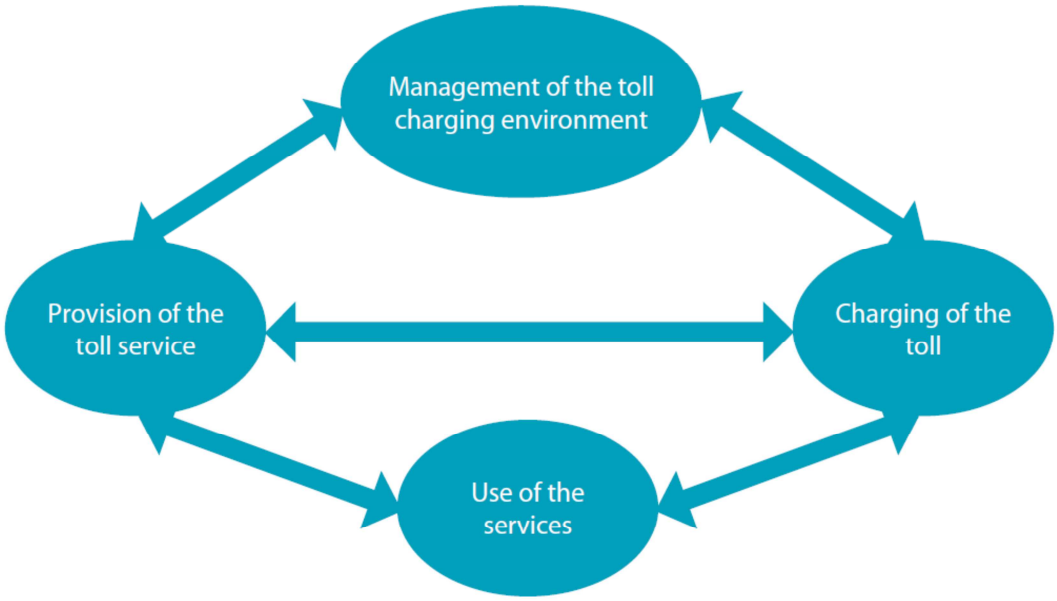

Figure 27: Main roles in EETS

The EETS Directive requires one or more of the prescribed technologies, being:

- GNSS (satellite: GPS; EGNOS, Galileo)
- DSRC (5.8 GHz CEN standard; in Italy UNI 10607)
- GSM/GPRS

The technology used in the OBU must be able to support enforcement and control of the Toll Charger. Also the road side unit has to support all the data exchange in the Electronic Toll Collection dataflow as shown in the following figure:

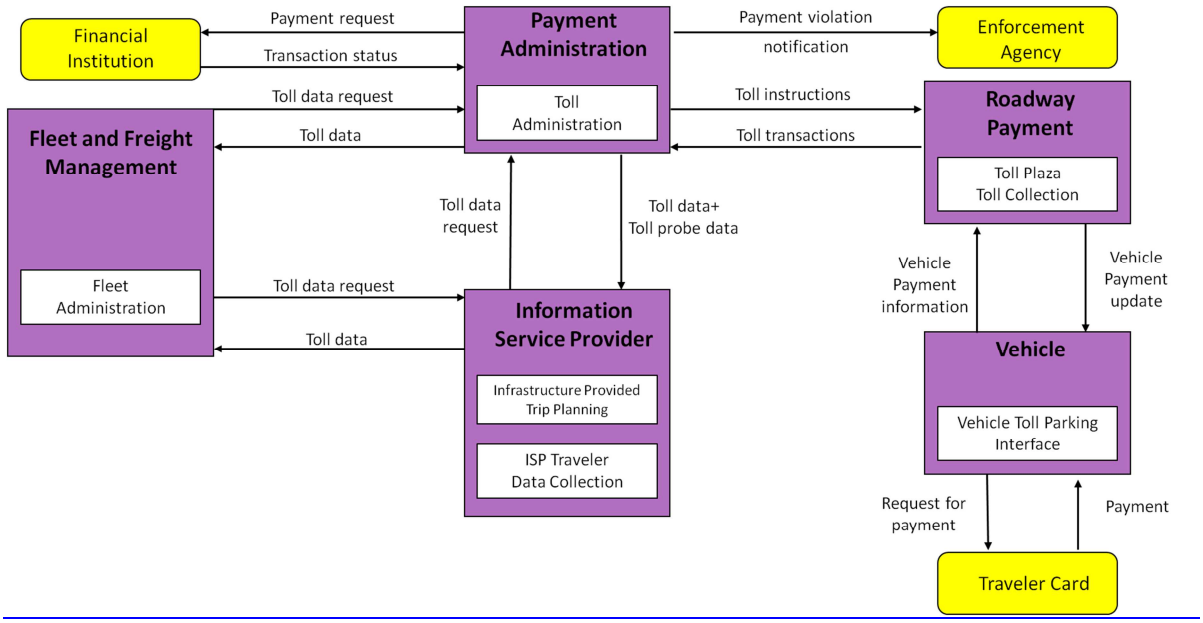

Figure 28: ETC Data Flow

Assessment of the technology

Implementation of the solution: Easy

Some civil works needed during installation but after that the system is normally ready to work.

Interoperability between different solution providers: Medium

There are European directives and decision (Directive 2004/52/EC, Decision 2009/750/EC, etc) which have in charge to assure the complete interoperability between the entire European toll charger in a European Electronic Toll Service.

Cost of the solution: Medium

There is a strong competition on the ETC market but the cost of the solution is in a medium range due to the complexity of the equipment installed

Security: High

The encryption method of the data transfer, the coverage of a wide area with each antenna and the use of enforcement systems makes this one of the faster and most reliable solution for the toll collection.

Safety: High

All the equipment has to satisfy the Europeans safety level for being sold as a part of an ETC system.

Efficiency: High

The standard of the market is 99,5% of good identification with vehicle running up to 180 km/h.

Maintenance: Medium

Very small maintenance needed, it depends on the environmental condition of the spot where the system is installed.

Usability: Easy

The system work with any effort or action on the user side.

Closeness to the market: Low effort

There is a strong completion on this market so almost any solution is easy to find.

4.9.3 Summary Assessment for Payment Systems

Evaluating the features of the toll collection methods defined in the present section, it is quite clear that, for the payment of FABRIC vehicles dynamic charging, the ETC systems, thanks the wireless communication between the on-board unit and the road side reader, are better suited than the stop and go solutions as smart cards and NFC device .

The toll payment systems, based on smart card or NFC mobile device, can be adopted in the case of the static charging of FABRIC vehicles.

Table 20: Summary assessment table of AVI technologies

	Smart or Credit Card	Mobile (NFC)	ETC
Implementation of the solution	Easy	Medium	Easy
Interoperability between different solution providers	Easy	Difficult	Medium
Cost of the ICT tools	Low	Medium	Medium
Security	N.A	High	High
Safety	High	Medium	High
Efficiency (usability and performance)	High	Medium	High
Maintenance	Easy	Medium	Medium

Usability	Easy	Medium	Easy
Closeness to market	Low effort	Medium effort	Low effort
Overall assessment	**Highly suitable for FABRIC (especially for static scenarios)**	**Suitable for FABRIC**	**Highly suitable for FABRIC**

4.10 Road operator modules/interface

The Traffic Management System (TMS) field is a primary subfield within the Intelligent Transportation System (ITS) domain. The use of different ITC technologies on field aims primarily to reach the following goals:

- Improve safety
- Increase transportation system efficiency
- Enhance mobility
- Reduce fuel consumption and environmental cost
- Increase economic productivity
- Create an environment for an ITS market

Real-time data from cameras, speed sensors, whether forecast, safety system of third part, etc. flows into a control room in a Transportation Management Centre where it is integrated and processed (i.e incident detection), and may result in action taken (e.g. traffic rerouting, VMS message) with the goal of improving traffic flow and safety for the users.

These Control Rooms are the centre of all the ITS and ICT system and equipment.

4.10.1 Typical Control Room Architecture

The majority of the Control Rooms on the market are based on a multi-tier architecture based on the separation of concerns principle.

In computer science, separation of concerns (SoC) is a design principle for separating a computer program into distinct sections, such that each section addresses a separate concern.

Concerns are the different aspects of software functionality. For instance, the "business logic" of software is a concern, and the interface through which a person uses this logic is another. The separation of concerns means keeping the code for each of these concerns separate. Changing the interface should not require changing the business logic code, and vice versa.

The value of separation of concerns is simplifying development and maintenance of computer programs. When concerns are well separated, individual sections can be developed and updated independently. Of special value is the ability to later improve or modify one section of code without having to know the details of other sections, and without having to make corresponding changes to those sections. Modularity, and hence separation of concerns, is achieved by encapsulating information inside a section of code that has a well-defined interface. Encapsulation is a means of information hiding. Layered designs in information systems are another embodiment of separation of concerns (e.g., presentation layer, business logic layer, data access layer, persistence layer). The most widespread use of this principle is the multi-tier architecture and, more specifically the three-tier architecture.

Three-tier architecture is a client–server architecture in which the user interface (presentation), functional process logic ("business rules"), computer data storage and data access are developed and maintained as independent modules, most often on separate platforms.

Apart from the usual advantages of modular software with well-defined interfaces, the three-tier architecture is intended to allow any of the three tiers to be upgraded or replaced independently in response to changes in requirements or technology. For example, a change of operating system in the presentation tier would only affect the user interface code.

Typically, the user interface runs on a desktop PC or workstation and uses a standard graphical user interface, functional process logic that may consist of one or more separate modules running on a workstation or application server, and an RDBMS on a database server or mainframe that contains the computer data storage logic. The middle tier may be multi-tiered itself (in which case the overall architecture is called an "n-tier architecture").

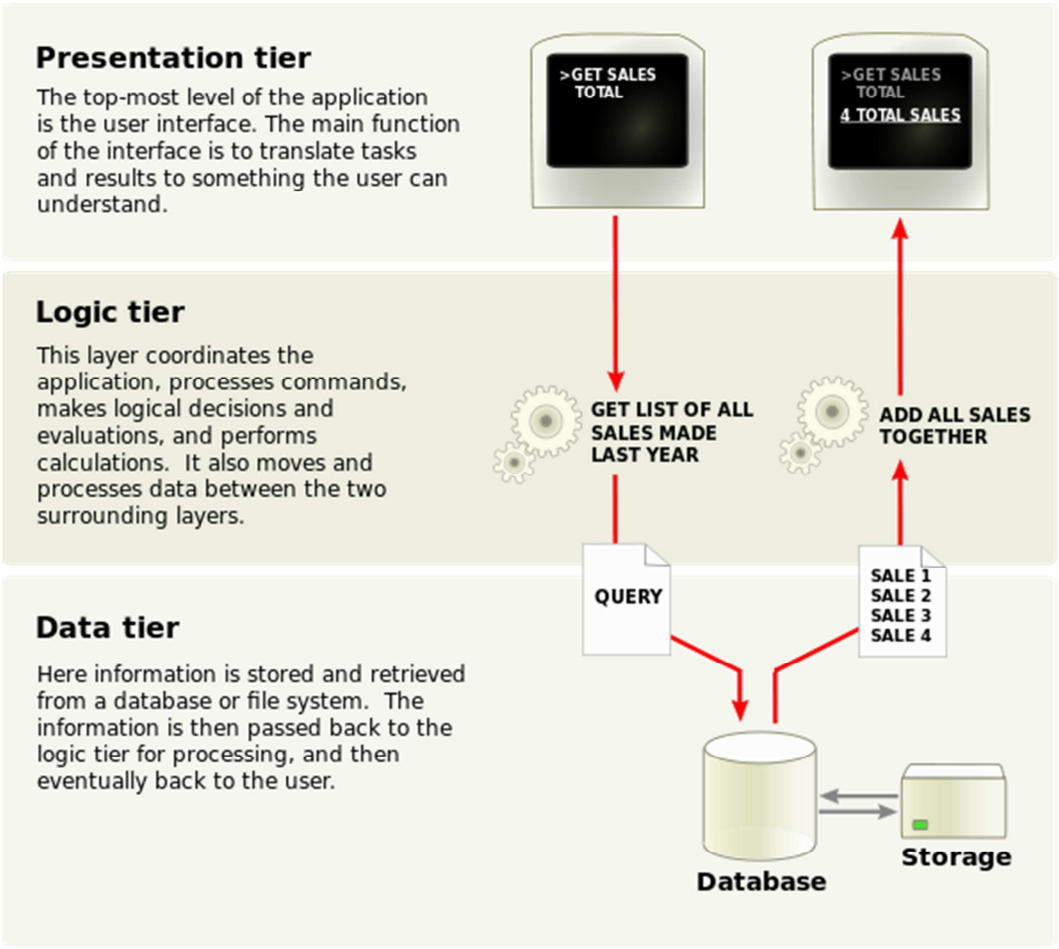

Figure 29: Three-tier architecture

The Control Room manages all the data coming from the system which are on the field, these systems are normally bought on the market so every sensor or equipment must be able to interface itself with the Control Room System.

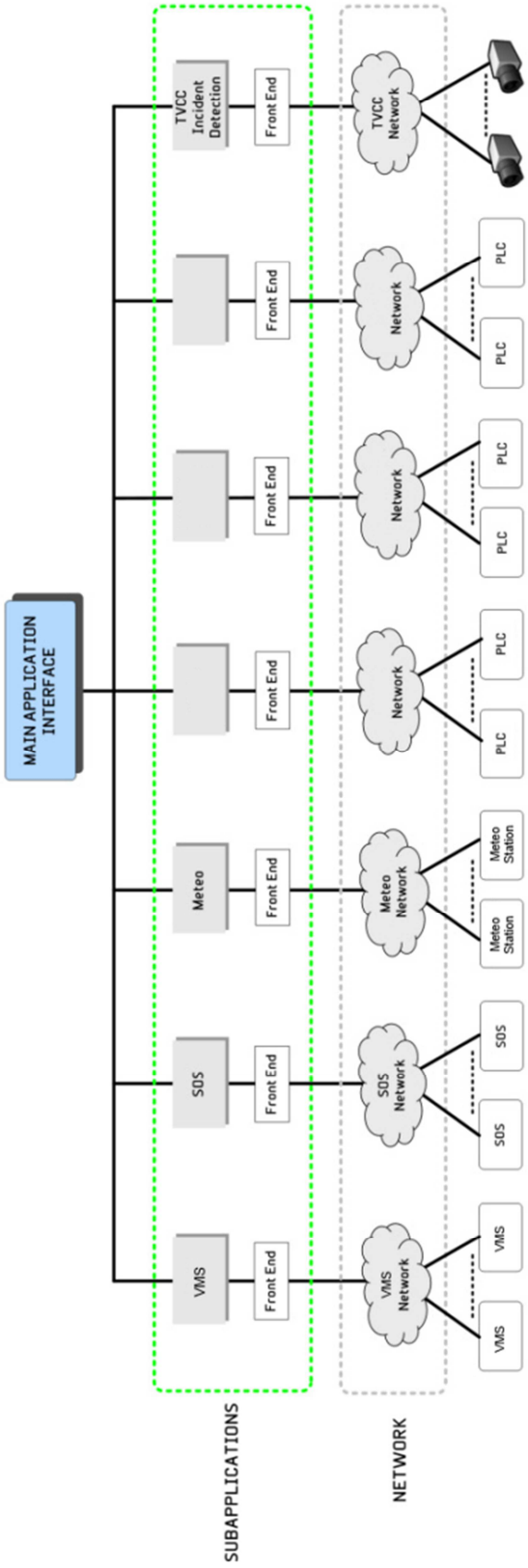

Figure 30: Control Room Logical Architecture

Implementing the European Transport policy of the European Commission as it is stated now in the ITS Action Plan implies co-ordination of traffic management and development of seamless pan-European traffic information services. For developing such services, data shall be collected, integrated/processed and exchanged among the traffic centres and with service providers. This brought to a formulation of a strategic framework, which would define common guidelines in order to achieve integrated ITS applications, interoperable and able to communicate through a shared language.

4.10.2 Communication standards towards Control Room

4.10.2.1 TRIDENT

European transport information is characterized by its local or restricted qualities. In order to develop systems that have wider regional, national and pan-European potential, it is first necessary to develop common specifications and standards for sharing and exchanging transport data. Earlier work has successfully developed standards for individual transport modes.

TRIDENT (Transport Intermodality Data sharing and Exchange Networks) is an European project (inside of the 5th RTD Framework Programme) which has been completed in 2003.

TRIDENT aimed to extend these standards to operate in a multi-modal transport environment, laying the foundation for the development of more comprehensive transport information systems and the achievement of significant improvements to the availability and accuracy of transport information across Europe.

Also, common and sharing and exchange specifications are a key enabling factor for service interoperability and customer roaming.

TRIDENT's intention was to develop specifications and software modules to enable the sharing and exchange of real-time multimodal traffic and traveller information through the whole Transport and Travel Information content chain.

Two different paths to achieve this goal were selected: One based on the "messaging approach" (EDI, DATEX) and the other one based on the use of more modern object-oriented (OO) technologies.

The aim of the EDI approach is to offer existing DATEX users a way to exchange a larger variety of content using their existing DATEX nodes as well as provide a first step of the migration path towards the OO technologies.

The aim of the OO approach is to offer new actors means to exchange the whole range of traffic and traveller information using modern technologies, yet fully taking advantage of the high level

of know-how obtained in developing the DATEX (road traffic information exchange) and TransModel (Public Transport reference model) standards.

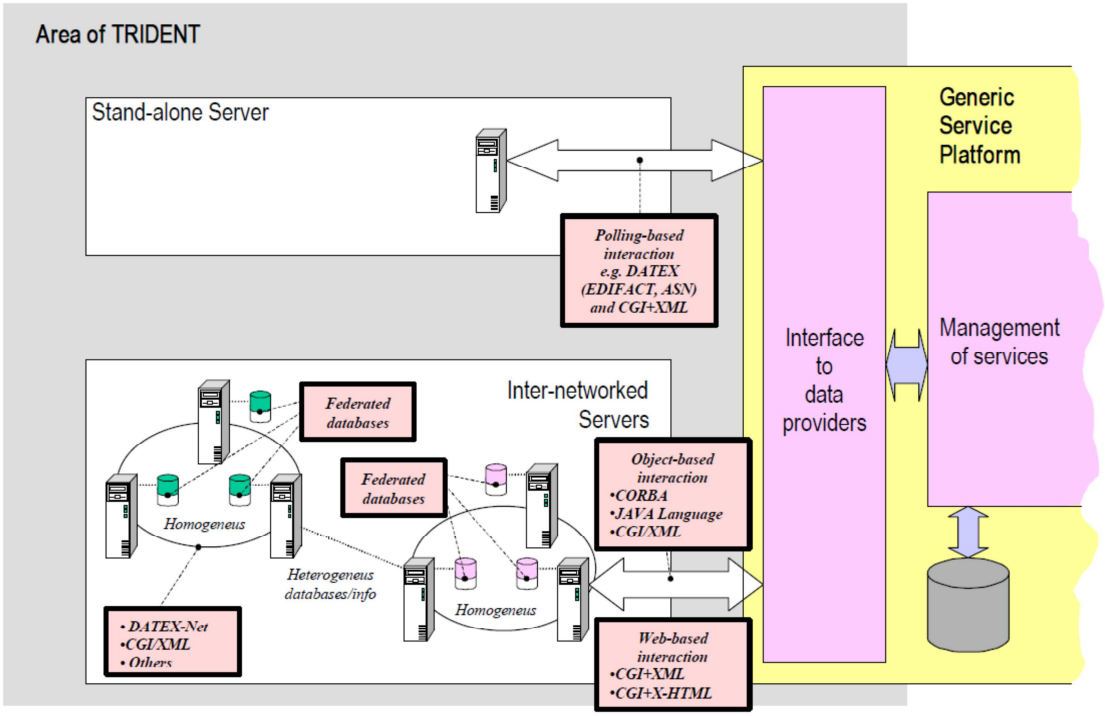

Figure 31: TRIDENT Architecture

TRIDENT reached its goals and produced two sets of specifications, implemented them at 4 test sites in Europe and produced the final specifications.

TRIDENT built and operated four different test sites: West Yorkshire, Rome, Paris and Flanders. All of the applications have proven successful, and continue to operate after the end of the project. West Yorkshire and Paris applications are already enlarging from the original demonstration sites to other areas and transportation modes, Flanders is used for assessing supply of public transport in altered demand situations and Rome is considering adding tourism information to the existing TRIDENT application.

Since the production of the first full draft of the OO specifications took a lot longer than expected, a recurring update procedure for the OO specifications was adopted, for as long as the specifications were at least to a small level acceptable by all the demonstration sites. This approach was chosen as it was realized that sites would run into enormous problems had they use the previous version of the specifications.

The final specifications and modules have been already released to more than 40 different organizations and companies in both Europe and overseas for evaluation purposes.

Specifications have been submitted to the CEN Technical Committee 278 working groups 3, 4 and 8. It has been recognized that the TRIDENT specifications will end up being a key European standard on multimodal information exchange.

4.10.2.2 RADEF

RADEF (Road Administration Data Exchange) is a collaborative project of the Western European Road Directors and is financially supported by the European Commission, Directorate General for Transport.

Developed by PMQP (Project Management and Quality Plan), has the purpose of administer the logical data model of the road data (LDM) and the Data Dictionary of the following areas: Road Network, Restriction, Traffic, Structure, Equipment, Accident, Condition, Road Geometry, Route, Network Inquiry.

ENTITY NAME	Code table cross-ref.	DOMAIN CROSS-REFERENCE									
		Road Network	Restriction	Traffic	Structure	Equipment	Accident	Condition	Road Geometry	Route	Network Enquiry
ACCIDENT							✓				
ACCIDENT POSITION TYPE	CV7						✓				
ACCIDENT PREVENTION	CV25						✓				
ARC									✓		
ARC POINT									✓		
ARC POSITION TYPE	CV22								✓		
ARTIFICIAL LIGHTING CONDITION TYPE	CV13						✓				
BORDER CONNECTION		✓									
CONDITION CROSS SECTIONAL POS	CV23							✓			
CONDITION LEVEL TYPE	CV9							✓			
COUNTRY	CV2	✓			✓	✓				✓	✓
DIRECTION	CV6	✓		✓							
EQUIPMENT CROSS SECTIONAL POS	CV8					✓					
EQUIPMENT DETAIL						✓					
EQUIPMENT ITEM						✓					

Figure 32: Example of the data model of the road data

4.10.2.3 TRANSMODEL

TRANSMODEL is a description of the data of interest to a company in designing an Integrated Information System.

TRANSMODEL is a conceptual model and does not mandate any particular implementation at the logical or physical level.

Therefore, TRANSMODEL can be implemented on several different platforms.

What are the requirements for such a reference data model:

- To promote a common integrated approach in the design of an Information System
- To allow an open architecture
- To enable easy adaptations to the specific needs of European operators
- To guarantee a reliable exchange of information between different software products.

TRANSMODEL increases the efficiency of transport operations by underpinning them with more secure and reliable Information Systems. TRANSMODEL is also expected to open the market by allowing integration of complementary software products from different suppliers.

The present version of TRANSMODEL (V5.0) uses an Entity-Relationship modelling approach and covers the following domains:

- Tactical planning,
- Personnel disposition,
- Operations control,
- Passenger Information,
- Fare Collection and Management Information/Statistics.

TRANSMODEL is being developed by a European team within which various levels of end users are represented. It has been presented at many conferences and discussed within seminars open to transport and information modelling experts. It has received, and still receives feedback from a wide audience. It is continually evolving to incorporate a variety of new points of view.

TRANSMODEL is now on the path to becoming a European standard reference.

The domain of operations monitoring and control, which is the one fitting our research most, concerns all activities related to the actual transportation process. It is also known as real-time control, or operations management.

The supply basis for each operating day is known as a production plan, composed of the planned work of each available resource (e.g. vehicles and drivers). It includes for instance all dated journeys planned on the considered day, including occasional services.

The transportation control process supposes a frequent detection of the operating resources (in particular vehicle identification and location tracking). Such collected information is compared to the planned data (e.g. work plan for a vehicle or a driver), thus providing a monitoring of these resources.

The monitored data is used for:

- controlling the various resource assignments (e.g. vehicle assignment to a dated block),
- assisting drivers and controllers to respect the plan (e.g. schedule adherence, interchange control),
- alerting on possible disturbances (e.g. delay thresholds, incidents),
- helping the design of corrective control actions according to the service objectives and overall control strategy; the model describes a range of such control actions (e.g. departure lag),
- activation of various associated processes (e.g. traffic light priority, track switching),

- passenger information on the actual service (e.g. automatic display of the expected waiting time at stop points),
- follow-up and quality statistics.

Other aspects, such as communication between actors, are taken into account.

4.10.2.4 DATEX II

With the aim of fostering sustainable mobility in Europe, the European Commission has been supporting for several years the development of information exchanges. Therefore, investments have been made to develop the DATEX standard and to implement it in traffic control and information centers in order to ensure interoperability and cross-border exchange over TEN-T.

It complies with the objectives of the EasyWay programme for safer roads, reduced congestion and a better environment. The new generation DATEX II has become the reference for all applications requiring access to dynamic traffic and travel related information in Europe. Its specifications take into account the new architecture for communication (e.g. Internet) and open the door to all actors of the traffic and travel information sector.

The DATEX II standard was developed for the exchange of road traffic information (in XML format, definitions of content are stored within a UML model) among road operators and between road operators and service providers.

DATEX II has become the reference point for all applications that require access to dynamic traffic (i.e. cameras and sensors on the road network).

The protocol DATEX II manages various types of information:

- Events related to road traffic
- Data from Sensors (flows of traffic, weather, etc.).
- Processed data (Times of distance travelled)
- Alerts and accidents
- Information on routes

One of the main objectives for DATEX II is to be platform independent.

The evolutions of ICT and the generalization of Internet and its standardized protocol (HTTP and SOAP), drove the data exchange applications and was taken up by DATEX II.

The modelling of the traffic information and control domain chose UML (Unified Modelling Language), standardized language widely used in many domains. Using DATEX II as a service does not depend on ICT infrastructure (outside internet connection) and is totally independent of any hardware or operating systems.

However in order to produce valuable dynamic information many application areas depend on the availability of valid information with high resolution in space and time. From the perspective of the Data Exchange specification, quality and content must be separated from processing this data. The DATEX II specification in itself does not limit the accuracy or reduce the overall quality of traffic information; however certain necessities have to be taken into account.

DATEX II functional architecture defines mechanisms and a functional model to exchange data. In a high level architecture, the key aspects are:

Work in different environments. Implementations may use any technology; each sender and receiver shall be, capable of using Internet and web-services for data exchange.

Exchanging Information

Based on widely used development patterns, exchange mechanisms can be implemented based on a publish/subscribe pattern; In this system there are two roles, supplier and client. The supplier publishes information, whereas the client subscribes it and receives traffic information.

Two data exchange modes are defined, pull and push. In pull mode, data is requested by a receiver from a provider, generally in a periodic way. In push mode, data is sent from a provider to a receiver, when it is available, being more suitable for scenarios where information should be available as soon as possible.

No restriction of exchange medium or network. DATEX II does not limit in any way the kind of connection that two parties use in data exchange. This can be reached using a dedicated connection, the public Internet, a virtual private network (VPN) or other, as long as there is the possibility to communicate over TCP/IP.

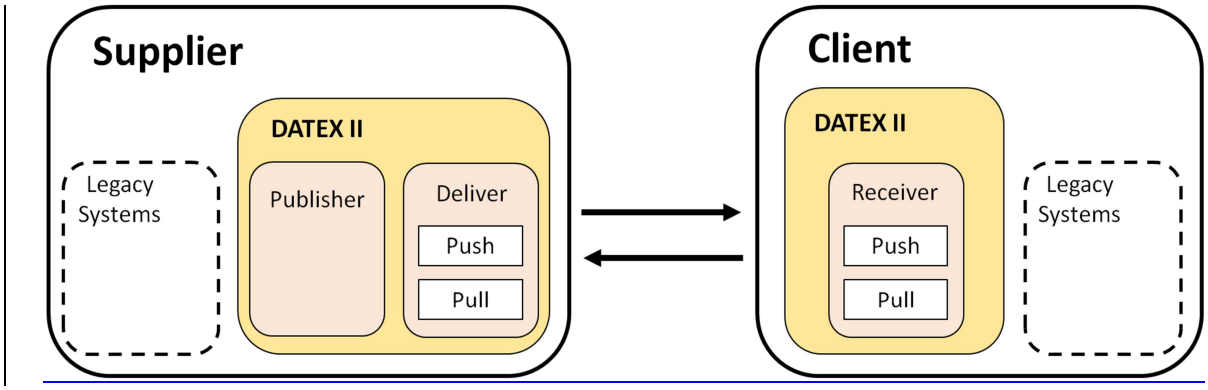

Figure 33: Architecture of DATEX II

A supplier exchange system is composed of two main subsystems:

- A Publisher subsystem, which makes data available and creates the payload publications (Situations, Traffic View, Measured and Elaborated Data, Locations)

- A Delivery subsystem, which adds exchange specific information and performs the physical delivery, supporting pull and push methods;

A client exchange system is composed of one main subsystem:

- A Receiver subsystem, which is responsible for receiving information, either by calling the supplier services (Pull) or receiving a service call made by the supplier (Push);

Legacy systems, which can appear beside a DATEX II system in the previous figure, represent any specific system that is not DATEX II-native. Generally these systems have been designed before introducing DATEX II. The term is widely used in DATEX II literature and beyond.

A subscription is a mechanism set up between a Client and a Supplier that specifies the payload type to be exchanged. It can be defined by the supplier or by the client. DATEX II allows users to have the freedom to develop subscriptions with the refinements they need.

There are 3 possible operating modes for data delivery:

- Publisher Push on occurrence Data delivery, each time data is changed the information is sent to the client by the supplier;
- Publisher Push periodic Data delivery, the supplier publish data on a cycle time basis and send it to the client;
- Client Pull Data delivery is initiated by the Client and data is returned by the supplier;

At the technical level, DATEXII distinguishes two kinds of systems:

- Push systems
- Pull systems

A Push system can use both Push modes of data delivery and DATEX II proposes to make the implementation with Webservices over HTTP, implemented on both sides.

A Pull system uses the Client Pull mode and DATEXII proposes to make the implementation with:

- Webservices over HTTP,
- HTTP web server with an XML data file.

According to the adopted implementation by the supplier, the Client uses either:

- Webservices over HTTP,
- Basic HTTP requests.

4.10.2.5 Summary Assessment for Road Operator Interfaces

The evaluation stated in the following table is directly taken by the dissemination activities of the relative project in which the data exchange model was developed. In exception for DATEX2 all

the other system listed are not used by actual road operator control room, because they are project in developing or only conceptual methodology. As DATEX is a common standard for this kind of applications, it's the obvious choice for the FABRIC's Road Operator Interface.

Given that DATEX II has established itself as the standard for the development of an interoperable ITS application, it is clear that the interface between the FABRIC platform and the road operators will only has advantages using DATEX II architecture for the data exchanges.

Table 21: Summary table of technologies

	TRIDENT	RADEF	TRANSMODEL	DATEX II
Implementation of the solution	Difficult	Medium	Difficult	Easy
Interoperability between different solution providers	Medium	Medium	Medium	Easy
Cost of the ICT tools	Medium	Low	High	Low
Security	N/A	N/A	N/A	N/A
Safety	High	Low	High	High
Efficiency (usability and performance)	Low	Medium	Medium	High
Maintenance	Medium	Medium	Medium	Easy
Usability	Medium	Easy	Medium	Easy
Closeness to market	High effort	High effort	Medium effort	Low effort
Overall assessment	**Not suitable for FABRIC**	**Not suitable for FABRIC**	**Not suitable for FABRIC**	**Highly suitable for FABRIC**

4.11 DSO and Retailer modules/interface

The scope of this section is to describe and evaluate the existing ICT solutions for (Distributor System Operator) DSO and Retailer in grid infrastructure to be applied for future distribution of electric vehicles supply system.

The focus is to examine ICT methods and technologies currently in use in the different level of distribution for the energy measurement and cost construction in the relationship among Distributor (DSO), Retailer and Clients. It has to be considered that the solution could be applied both to the low voltage and to the mid voltage range and then this will be the measurements solution analysed. The different possible charging solutions can, in turn, have many different accounting approaches both with the DSO and with the Retailer, leading to different possibility in contracts and power supply.

The study has been focused on the Italian and Spanish electrical market, but ICT technologies are similar to the ones that can be found in any other country.

4.11.1 ICT solutions in Italy

The technologies considered represent the state of the art of the measurement in Italy and it will include:

- DSO communication infrastructures
  - Measurement and communication infrastructures for low- and mid-Voltage distribution
  - Data exchange formats between DSO and Retailer
- Retailers
  - Measurements and billing possibilities
  - Programs for the price construction in the free market

4.11.1.1 DSO ICT Solutions

The actual distribution system and related metering solution in Europe differs country by country. Some common structure in the smart city environment can be anyway identified.

In Figure 34 the architecture of a simplified Smart Metering system is presented. The metering purpose in the smart city will probably be based on a multi-utility gateway connected with the measuring instruments in Power Line Communication (PLC) or Low Power Radio Frequency (RF). The same connection can be identified between the metering gateway and the Data Concentrators. From this point the communication the Metering Service Provider and the Back office is on TCP/IP. Sometime the TCP/IP connection is foreseen till the Metering Gateway, which can be included into the measuring instrument itself.

The solution shown in Figure 34 is an ideal one and based on the new planning metering process for every kind of energy service. The actual situation of the metering systems in the electric energy distribution in Italy is approaching this solution but it is not yet implemented in a complete form.

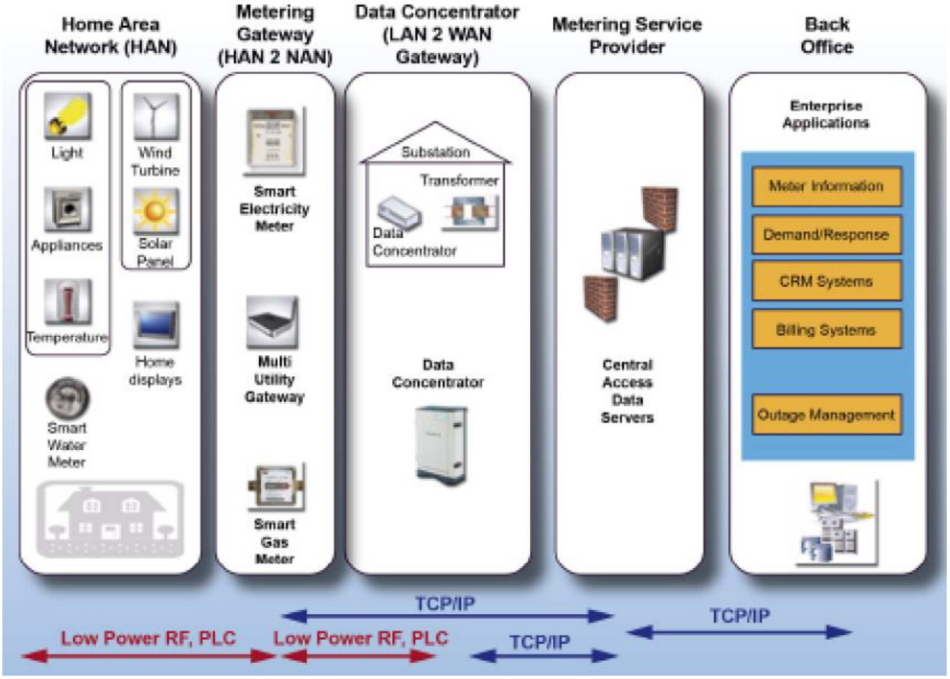

Figure 34: Architecture of a simplified Smart Metering system

The described architecture is foreseen for every kind of distribution form the extreme low power of the house consumption to the large factory and even to the large green energy producer.

Considerations to the electric automotive world, in fact, will be different if a small charging park or an electrified highway is considered. The first system can be a Low Voltage (LV) connection while the second can be a Medium-Voltage (MV) one considering the different power request: some 100kW in the first case, some MW in the second.

The actual system for the energy measurement is based on Smart Meters (SM) directly connected to the Point Of Distribution (POD) and are managed by the Distribution System Operators (DSO).

- In Italy, as in many European Countries, these measurements are the **only one legally valid**. Other measurement instruments can be placed by the Retailer in accordance with the Client but they are not valid to create the energy bill. These latter measurements can be adopted to make consumption estimation a give an immediate feedback to Retailer and Client.

Figure 35: Smart Meter for Energy measurements in Italy

In Figure 35 a measurement system for the 3-phase distribution is shown. It can be both unidirectional and bidirectional (that is being able to measure power entering back the grid), with a direct connection or with an indirect connection (that means using voltage and current transformers).

The capabilities of the SMs in power control, metering and communications changes as a function of the required supply lines and power level. For low power application, which is below 30kW, the power meter is often inserted in the line and uses direct current and voltage measurements. In these conditions the SMs offer the possibility to control and limit the maximum power delivered to the client. A disconnection is automatically actuated if the delivered power exceeded the maximum (or the 120% of the maximum power for a short amount of time).

Connections with large power requirements (larger than 55kW) are typically unlimited in power delivering and power is measured with indirect connections.

The measurement capabilities of the modern Smart Meters are wide and independent of the power delivered, these instruments can store at least:

- Active energy
- Reactive inductive energy
- Reactive capacitive energy
- Maximum power

The acquisition rate can be really fast (say seconds) and, considering that the stored data are integral or maximum values, they can be sampled in different time stamp.

In terms of billing the time unit is the month, it can be reduced to the hour or to the quarter of hour considering the fluctuation of the energy price into the free market. Faster sampling time

can be obtained by the new instruments and it can go down to the minute. This fast solution can be applied to the large power demanding clients.

The standard accounting time rate is, anyway, the hour. Each day than contains the indication of the hourly consumption for each POD, even if, as said, the metering capability is much higher.

4.11.1.1.1 Power Line Communication

Small metering systems for low power distribution line (typically in LV configuration) can be connected to the Data Concentrator inside the substation cabin via the power line itself with what is called Power Line Communication (PLC).

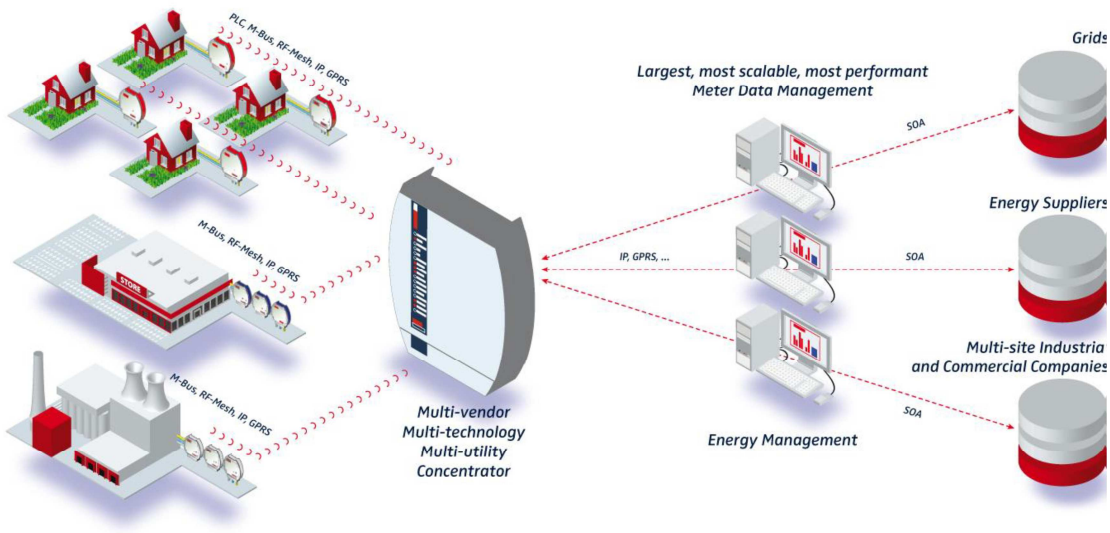

Figure 36: Communication configuration for LV distribution systems

The scope of the Data Concentrator is to collect the data form the different Smart Meters connected and communicate the acquired data to the DSO data central.

The communication channel in the metering concentrator are typically actually in Low Power RF or Global System for Mobile communication (GSM) or General Packet Radio Service (GPRS) based, in case no channel in the dedicated RF range is available in the substation site.

If the Smart Meter is placed on a large (>100kW) passive client (a client that do not produce electric energy) the communication in the HV-MV substation cabin is directly connected to the DSO data central with the same physical channels.

4.11.1.1.2 Low Power RF

The main problem in finding a communication protocol suited for the RF communication is the frequency that has to be adopted. Recent normative in EU had opened the following frequency to the possible use in smart metering:

- 169MHz (ETSI EN 300220-1 v2.3.1 for future EN13757 inclusion)
- 433MHz (EN13757-4 incomplete and depends on the local authorities)
- 868-870MHz (EN13757-4)
- 2.45GHz

The lower the frequency is the larger is the communication distance but the lower are the available channels with the same communication rate.

Actual solutions in Italy look for the 169MHz frequency adoption based on WM-Bus communication protocol, or in alternative the 868MHz one with the same protocol. If the RF signal is too low the alternative GPRS solution is foreseen.

4.11.1.1.3 GSM/GPRS Communication actual solution

The physical “channel” to access the SM measurement is the air. It is actually based on the GSM/GPRS technology but can be turned in any other as a function of its availability in the distribution point.

Commands are sent via GSM to the Data Concentrator or Smart Meter directly so we can talk more of remote-control rather than remote-measurements. The principal command is the monthly reading. If a concentrator receives this command start to communicate via power line with the different Smart Meters to acquire the final measurements of the previous month.

To this purpose each Smart Meter is provided with different registers:

- Last month register
- Quarter hour register
- Hour register
- Actual register

When dealing with payment, the first register (last month) is requested to each smart meter. Data collected are sent to the DSO data central that organizes the acquired data.

Among the different commands the quarterly measuring graph can be asked too to all the actual SM installed in Italy. The amount of data is this way strongly increased and only one SM per Concentrator can be monitored at time. The reason to use this procedure is typically a problem in the differences between usual class of consumption and actual readings.

4.11.1.1.4 WM-Bus and M-Bus

Among the different protocols available for the Smart Metering, not only in the energy world but also in the Water, Gas and similar services, the M-Bus protocol has been chosen in many European Countries as a standard. The WM-Bus is the same application in wireless modality.

The possible communication mode in WM-Bus is coded by the standard EN13757-4 and is represented in Table 22.

MODE	Direction	Data rate and coding
„S" (Stationary): S1; S1-m;S2	5„S1" – Uni-directional „S2" – Bi-directional	TX: 32kcps, Manchester RX: 32kcps, Manchester
„T" (frequent transmit): T1;T2	„T1" - Uni-directional „T2"- Bi-directional	TX: 100kcps, 3-out-of-6 RX: 32kcps, Manchester
„R" (frequent receive) R2	„R2"- Bi-directional	TX: 4.8kcps, Manchester RX: 4.8kcps, Manchester

Table 22: WM-Bus Modes (da EN 13757-4:2005)

The parameters for the T-mode communication modality are shown in Table 23. The M-Bus protocol is the base on which the WM-Bus has been extracted. It is based on a 2-wire solution with 24-36 voltage variation in a multi-client structure it is structurally identical to the Controller Area Network (CAN) solution adopted in automotive and industrial communications. The CAN protocol as well as the M-Bus is considered for the Home Area Network (HAN) as well as many other proprietary protocols in order to connect the different meters inside the client distribution system.

Table 23: RF parameters in T-mode

Common Radio Parameter (T-Mode)	Min	Typical	Max	Unit	Comment
Frequency Band	868,700	868,950	869,200	MHz	500 kHz channel
Modulation		2-FSK			
Transmit Radio Parameter	Min	Typical	Max	Unit	Comment
Carrier Frequency	868,90	868,95	869,00	MHz	± 60 ppm
Frequency deviation	± 40	± 50	± 80	kHz	
Baud rate	90	100	110	kBaud	
Baud rate drift Transmitter			± 1 %		
Receive Radio Parameter	Min	Typical	Max	Unit	Comment
Sensitivity (BER < 10^{-2})	-100	-105		dBm	
Baud rate	88	100	112	kBaud	
Baud rate drift			± 2 %		
Adjacent Channel blocking	40			dBm	Extra requirement in WMBUS
Blocking ± 2 MHz	- 69			dBm	

4.11.1.1.5 Data exchange

The main aim of the data communication is ACTUALLY the billing process. The typical form of the data exchanged is, for large power clients, usually based on the hour management and 24 information per day are stored for each Point of Distribution. The month accounting is anyway always present because the communication capability is not always assured by the actual communication channel and, more than this, is legally mandatory.

The actual regulation, in fact, has to consider all the possible combination of Timed and Not Timed Power Lines. Timed Power Lines are the one in which a hourly metering system, the Not Timed Power Lines do not have such feature in the Metering technology.

The information between the DSO and the Retailed are regulated with a precise agreement and often based on the monthly grouping approach. That means, each month measurement data have to be sent to the Retailer, this communication includes errors, correction, forecast and forecast adjustment if, for some reason, the acquired data were not be available at the billing day.

The data exchange is almost automatic and based on a CSV or XML file. It is managed by a proprietary communication (TCP/IP based) line and stored into a web server from which the related Retailer can extract the information for a client.

Data from the DSO to the Retailer (and possibly to the Client) should be exchanged with a standard format that is the XML file format. The reasons for this choice are the following:

- Easiness
- Not proprietary
- Parsing speed
- Required ’overhead
- Grammatical existence
- Safety
- Obligations management
- Rules authority

The communication channel is usually internet via web-server of application-to-application solution as a function of the number of nodes that the Distributor manages.

The size of the files has to be smaller than 10MB.

The number of error or possible accident that can occur to the data, Smart Meter, and readings are really wide and a different approach can be followed if a DSO with a small Retailer should exchange data for a specific “problematic” client. This data can be actually humanly elaborated and sent by certified e-mail.

4.11.1.1.6 XML file structure

The structure of the file is purposely defined and had to contain a large series of information subdivided into 3 groups:

- Header: containing an ID of the communication kind (forecast, correction, readings, etc.) the sender and the receiver VAT information.
- Data and the identification of the POD, the data, the identification, the active energy, the reactive energy (actually only the inductive one), the maximum power and a flag that identify if the data transmitted are estimated or real values.
- Smart Meter data: fundamental data of the smart meter like Serial Number and installation date.

The File structure slightly differs in the Italian regulation with 9 possible accordances as a function of the different metering system:

- Periodic measurement with Timed Power Lines (TPL)
- Periodic measurement with Not-Timed Power Lines (N-TPL)
- Correction of a TPL
- Correction of a N-TPL
- Client switching data for TPL
- Client switching data for N-TPL
- Client switching historical data for TPL
- Client switching historical data for N-TPL
- Client switching initial functional data for N-TPL

4.11.1.2 Retailers ICT solutions

4.11.1.2.1 The Free Market and the National markets

The free market in the Energy into the European Union had introduced a further figure between the Client and the Distributor, it is the Retailer that is, in turn the one who sell Energy to the Client.

Some exceptions are anyway considered for big consumer like Trenitalia in Italy in which the Distributor and Retailer function is concentrated in the same entity. This exception is mentioned because in some solution of the Charge While Driving (CWD) system, the system became so big to be compared to a railway solution (SCANIA proposal) having a 1 to 10MW/km power consumption.

All information is actually collected by SAP or similar large data base and ready for any possible analysis.

Measurement points can be placed also by the Retailer itself if the billing process became too slow or if both the Client and the Retailer agree to the choice. This approach leads to a faster and easier relationship between the Retailer and the Client (the Charging Station Operator in FABRIC context).

4.11.1.3 Energy calculation

The availability of the data to the Retailer depends on the ICT infrastructure of the DSO. Information is retrieved typically form a Web Server in protected way.

Measurement points can be placed also by the retailer itself if the billing process became too slow or if both the client and the retailer want to have a better forecast of the upcoming billing process.

An example of available metering solution is shown in Figure 37.

Figure 37: Smart Meter for Retailer example

The principal communication capability of the model shown in Figure 6 are TCP/IP – PSTN – GPRS – M-Bus , as well as any RS232 or RS485 able to connect with any other communication system.

4.11.1.4 Billing possibilities

We consider here some possible configuration for the Italian market in which the Retailer can catalogue different clients:

- Private client small power. Contracts below 50kW peak installed power. Distribution and measurements are typically in LV systems the billing monthly based
- Aggregated clients. These clients are large companies with many different sites in which the metering procedure is performed over distinct power line possibly managed by different DSO. In the Italian environment it is possible to create a unique billing process for such a client. This solution can be reasonable for the EV charging process.

- Large client: large power consumption in single sites
- Huge client: they became DSO the amount of power is so large that they own the distribution line itself.

The galaxy of the possible contracts is really wide, some distinction can be made among the fixed cost old styled way to buy and sell energy and the actual variety of Retailer do not let see a unique solution.

The main problem for the EV charging process is that the usual actual client is a public entity that typically has standard contracts with a constant kWh cost.

4.11.1.5 Programs for the price construction in the free market

The actual programs to establish the cost of the energy to a specific client is based on Financial Theories approaches. The goal of the competition is the capability to predict the consumption thanks to a good model of the typical client.

In the view the charging solution is a pretty new application and differ in the classical clients different programs can be used but no indication are actually available for the

4.11.2 ICT solutions in Spain

The “DSO Interface” and “Energy retailer interface” agents represent two examples of the consequences of the introduction of new services in the electrical grid, such as Electrical Vehicle charging control. The first one includes the new systems and resources that the DSOs must develop in order to manage the impact that the EV charge implies on their facilities and operation. It shall interact mainly with the “FABRIC electric mobility platform”, demanding and providing the required data and processes to perform the new services. On its behalf, the “Energy retailer interface” supposes a fully new agent, which mainly focuses on the purchase and sale of energy, for its retail trade. Therefore, the interaction with the DSO and the Mobility Platform must be continuous, as well.

These modules come up as a response to the new paradigm originated by the Electric Vehicle Charge Control, whose infrastructure, regarding integrated wide-area deployments and grid adaption, is being developed taking very short steps. Consequently, it is difficult to find commercial solutions or technologies of direct and immediate application. In addition, it is possible, in most of cases, that the “DSO interface” shall have to be integrated in the current corporate systems of the companies.

As seen in section 4.2, the use of Service Buses and Web Technologies can offer the resources needed to build up these systems, so this chapter focused in proposals for the architectural definition of the “DSO interface” and “Energy retailer interface”, in order to summarize their functional objectives, which justify the use of the technologies that shall be detailed. Their feasibility shall be evaluated according to the methodology of this deliverable.

This approach meets the one found in other projects related to Smart Grid and, in particular, Electric Vehicle. **ELVIRE** (http://www.elvire.eu/) and **CENIT VERDE** (http://www.cenitverde.es/) are two examples of effort dedicated to study, define and assess the business cases and system architectures needed for the holistic implantation of the EV charge infrastructure. This way, the foundations for the selection of the appropriated ICT technologies are established. A brief summary of both initiatives is presented in the following points:

- **ELVIRE** project, belonging to FP7 of the UE and with a budget over 9 M€, has as main objective the development of "*innovative Information and Communications Technologies and service concepts*" in order to "*ease and optimize energy management of Electric Vehicles (EV) and to cope with the sparse distribution of electrical supply points during the ramp-up phase*".
- **CENIT VERDE** was born in Spain, with the support of the Government, by the impulse of a big consortium (including Seat, the national car manufacturer, and the two main Spanish DSOs, Endesa and Iberdrola), to design a complete EV charging infrastructure, from the Vehicle and Charger to the DSO systems. Its budget reached near 40 M€.

This shows that there exist, in spite of the difficult and slow deployment of big EV charging infrastructures, previous and present projects that align with FABRIC objectives and perspective. This chapter (4.12) hence presents the main operations that will take place in the corresponding modules. Since their IT implementation shall take advantage of the developments regarding FABRIC Mobility Platform and the corporate resources of the DSO, the focus is set on applicable technologies for the interface between the DSO and the Retailer. This interface is based on a communication from a central location or data center to another, so TCP/IP solutions and secure Internet access shall be required. Under that assumption, several communication protocols which may be feasible in this context are evaluated.

4.11.2.1 DSO Interface

DSOs shall have to enable dedicated systems to manage the new services introduce by EV charging. Without letting aside the interaction with the current operations and monitoring systems, new functionalities must be added to their corporate control centers.

4.11.2.1.1 Functional architecture

The proposed preliminary functional design is shown in the next image. Apart from the mandatory ICT interface, four big blocks are defined, which shall require permanent interaction and data exchange. The main external agents related to the DSO Interface are "FABRIC electric mobility platform" and "Energy retailer interface", as stated in Figure 2 of this document. More details about each subsystem's responsibilities can be found in Annex 9 ANNEX III: Additional info on DSO and Retailer Modules interface.

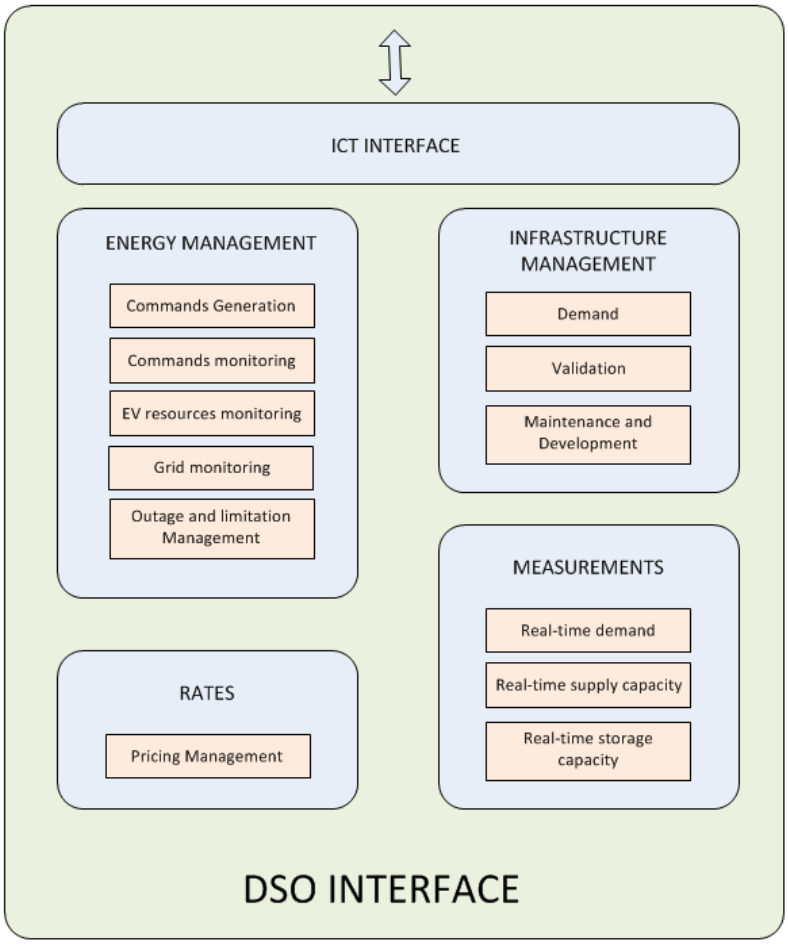

Figure 38: Functional architecture of DSO interface

4.11.2.2 Energy retailer interface

The “Energy retailer interface” agent is a figure that comes up from the opportunities of the new market. It shall be devoted to the purchase and retail trade of energy, for EV charging services.

4.11.2.2.1 Functional architecture

Due to the nature of this agent, its functional blocks are oriented to client interaction and commercial transactions of energy. More details about each subsystem’s responsibilities can be found in Section 9 ANNEX III: Additional info on DSO and Retailer Modules interface.

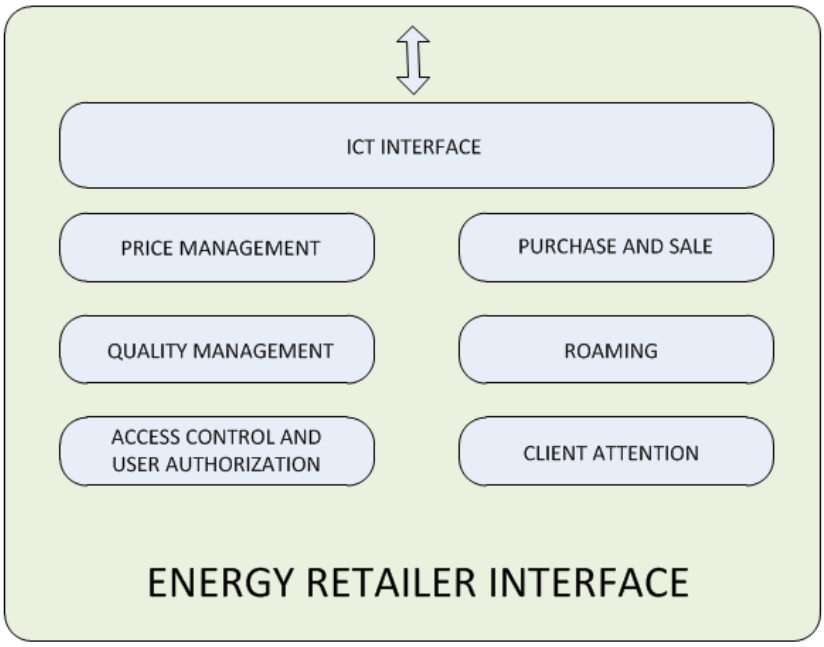

Figure 39: Functional architecture of Energy Retailer interface

4.11.2.3 ICT Technologies

The methodology used in Smart Grid developments is always looking for interoperable, standard solutions. That is the reason why “top-bottom” approaches for design or analysis are commonly found, from use cases and data models to the assessment of suitable technologies.

The evaluation presented in this chapter, as well as the perspective of FABRIC project, also goes in that direction. The main goal of the previous sections is to show, through an overview of the structure and functionalities of the DSO and Energy Retailer, the nature of the operations that shall be carried out to support new EV charging services. As seen, these actions can be summarized as exchange of high level information between complex, large-scale systems, such as data centers or front-ends for the remote control of the electrical grid. This includes signals, statuses, commands and measurements.

IT developments are treated in a more detailed way in other Work Packages, focused on the central Mobility Platform. In addition, in most of the cases belonging to the scope of this chapter, they shall be influenced by the characteristics of the DSOs corporate systems. For these reasons, the technological evaluation performed in this chapter pays attention to suitable protocols for the interface between the DSO and the Energy Retailer. Three different technologies, fitting for TCP/IP networks and whose features meet the required characteristics explained in the previous paragraph, are outlined in the following sections:

- **Web Services:** interoperable, technology-independent set of mechanisms for the exchange of information between two interacting systems. Based in XML and Web protocols.

- **ICCP (Inter Control-Center Communications Protocol):** as the previous one, focused in the exchange of data between systems, specifically for Control Centers. Frequently used for the interaction between DSOs and TSOs.
- **IEC 61850:** international standard created for SAS (substation automation systems), but extended to other applications. Signal reporting or command transmission over MMS can be found in their specifications.

4.11.2.3.1 Web Services

Internet is based on a client – server architecture, but not always the user is a person. Sometimes the user is other server and then, a machine-to-machine interaction is necessary.

A Web Service is a method of communication that enables two different software systems to exchange information over a network. For example, a company with a central office and branch offices all over the country, which takes a centralized inventory control. Each branch office has a Web Service which is consulted, takes a product ID and returns the amount of this product. This Web service is usable by the central server for the stock control, by a sales rep with a cell phone or by the supplier company.

This technology provides interoperability between two applications using different programming languages and running in different platforms. This is achieved by using open protocols.

Three basic elements define a Web Service:

- **SOAP** (Simple Object Access Protocol)
- **WSDL** (Web Service Description Language)
- **UDDI** (Universal Description, Discovery and Integration)

More details about Web Service technology can be found in Section 9 ANNEX III: Additional info on DSO and Retailer Modules interface.

4.11.2.3.2 ICCP

Inter-utility real-time data exchange has become critical to operations of interconnected systems within the electric power utility industry. Historically, utilities have relied on proprietary, non-standard protocols to exchange real-time data. ICCP began as an effort by power utilities, several major data exchange protocol support groups (WEICG, IDEC and ELCOM), EPRI, consultants and a number of SCADA/EMS vendors to develop a comprehensive, international standard for real-time data exchange within the electric power utilities industry.
In order to define the protocol, the Utility Communications Specification (UCS) Working Group was formed to:

- Develop the protocol specification.
- Develop a prototype implementation to test the specification.

- To submit the specification for standardization.
- To perform interoperability tests among the developing vendors.

Successful first implementations of ICCP between SCADA/EMS control centers led to further expansion to allow communications between control centers and power plants.

More details about ICCP technologies can be found in Section 9 ANNEX III: Additional info on DSO and Retailer Modules interface.

4.11.2.3.3 IEC 61850

IEC 61850 is an international standard for the automation of the control, protection and measuring functions in substations. This standard has been developed by the Technical Committee 57 (TC57) of the International Electrotechnical Commission's (IEC) in order to unify all communication protocols and achieve manufacturing interoperability.

The initial approach of the standard was the definition of an international standard for the communication between protection, control and measuring equipment within a substation. However, the use of the standard has been extended in applications outside the substation, i.e. communication between substations for protection functions (remote protections) or remote control between substations and control systems. Moreover, extensions of the standard have been developed for hydroelectric plants, wind farms and distributed generation. IEC 61850 has become one of the main protocols used in Smart Grids.

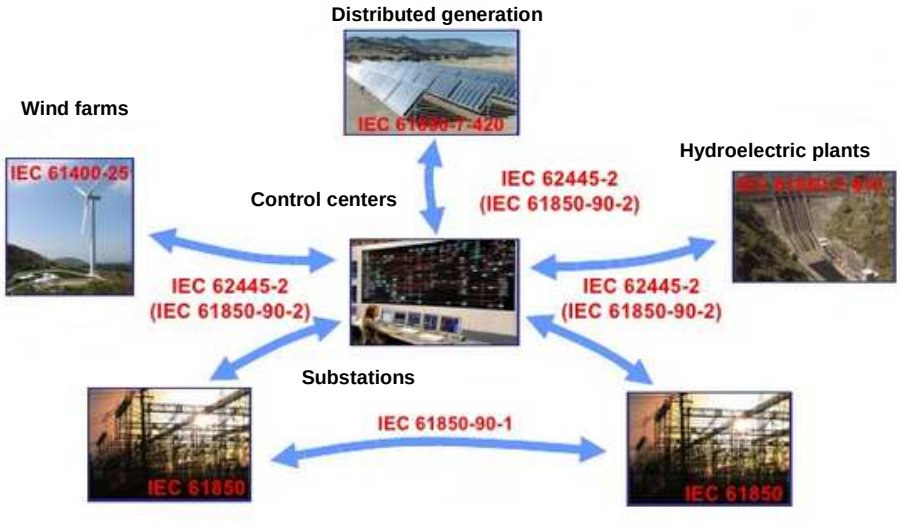

Figure 40: Scheme of use of different communication standards

The main objectives of its specifications are the following:

- Protocol unification, both standardized and proprietary protocols to achieve manufacturing interoperability.
- Improving the scalability of the installation.

- Easy configuration by using a standardized language.
- Wiring reduction.
- Reduction of maintenance costs.
- Definition of quality requirements and environmental conditions.

To achieve all of these objectives, the standard defines a data model to represent the information, the services specifying the actions that are able to perform with the information, the mapping of the services in communication protocols and a standardized language to configure the devices.

More details about IEC 61850 technologies can be found in Section 9 ANNEX III: Additional info on DSO and Retailer Modules interface.

4.11.2.4 ICT security

The technologies presented in the previous chapter are meant to work over TCP/IP Internet networks. Since this implies, often, the utilization of public infrastructures, due to the cost of deployment and maintenance of a proprietary wide-area network (WAN), security of the communications is a major issue. In addition, Smart Grid services often imply the management of private information from the clients or the users, which adds another important reason for the adoption of this type of mechanisms.

This section presents, from an introductory point of view, the principles of security applied to ICT. The implementation of these solutions supposes the need for more resources regarding processing capabilities, communication bandwidth or systems capacity and features. It is important, then, to take them into account when evaluating the feasibility of the protocols involved in the DSO and Energy Retailer interactions.

Over the last few years, there has been a boom in the last generation ICT technologies. Its incorporation to the electrical utilities has generated a set of new vulnerabilities that was not exposed to before.

It is necessary to analyse the existing vulnerabilities in order to protect the system from possible attacks. Generally these are the basic security requirement:

- **Confidentiality:** protect against the disclosure of information to parties other than the intended recipient.
- **Integrity:** allow the receiver to determine that the information provided by a system is correct.
- **Availability:** Assuring information and communications services shall be ready for use when expected.
- **Non-repudiation:** ensure that a transferred message has been sent and received by the parties claiming to have sent and received the message.

More details about ICT security aspects can be found in Section 9 ANNEX III: Additional info on DSO and Retailer Modules interface.

4.11.3 Summary Assessment of DSO and Retailer modules/interface

4.11.3.1 Summary Assessment of Communication Technologies

Considering the different technologies that can be identified in the communication data from the SM to the DSO data central it has to be noted that the final line will always be TCP/IP.

The actual configuration of many of the SMs present on the markets either for billing purposes or for pure metering offers a really wide variety of communication protocols opening the door to any solution. Simultaneous data transfer of a wide number of POD could became a problem with the actual communication systems if the accounting process should have to reach the minute level.

The 24hour daily data communication or the 92 (96 for the day saving date) is a solution that can be acceptable and useful for any purpose, billing or clustering activity.

Table 24: Summary table of DSO communication technologies

	GSM/GPRS	M-Bus	WM-Bus
Implementation of the solution	Easy (low number of components and simple management)	Medium (cabled solution can be difficult)	Easy (low component, simple in a short range distance)
Interoperability between different solution providers	Easy (straightforward)	Easy (it is a standard)	Medium (it is standardized but different operator can use different communication channels)

Cost of the ICT tools	Low (both in components and management)	Medium (communication line can be suitable for low distance otherwise the cost and complexity can be too high)	Low (both in components and management)
Security	Medium (Simple encryption level)	High (point to point physical connection)	High (enhanced encryption level)
Safety	Medium	High	High
Efficiency (usability and performance)	High (simple, low consumption and robust)	Medium (simple, mid consumption level and robust)	High (simple, low consumption and robust)
Maintenance	Easy (really low)	Medium (some maintenance could be foreseen for the cabling)	Easy (being radio based is again a low Maintenance)
Usability	Easy (simple to use and to implement)	Easy (simple to use and to implement)	Easy (simple to use and to implement)

Closeness to market	Medium effort (In the Italian context some operators are using such a technology)	High effort (In the Italian context not that many operators are using such a technology)	High effort (In the Italian context not that many operators are using such a technology)
Overall assessment	**Suitable for FABRIC**	**Suitable for FABRIC**	**Highly suitable for FABRIC**

4.11.3.2 Summary Assessment of other baseline ICT solutions

Table 25: Summary table of technologies

	Web Services	ICCP	IEC 61850
Implementation of the solution	Easy (web technologies, open source)	Medium (need of specialised libraries and abilities)	Medium (need of specialised libraries and abilities)
Interoperability between different solution providers	Easy	Easy	Easy
Cost of the ICT tools	Low	Medium	Medium
Security	High (depending on ICT security measures)	High (depending on ICT security measures)	High (depending on ICT security measures)
Safety	Higher (reduction of wiring and accessible electrical connections)	Higher (reduction of wiring and accessible electrical connections)	Higher (reduction of wiring and accessible electrical connections)
Efficiency (usability and performance)	High	High	High
Maintenance	Medium	Medium	Medium
Usability	Medium	Medium	Medium

Closeness to market	Medium	High	Medium
Overall assessment	**Highly suitable for FABRIC**	**Suitable for FABRIC**	**Suitable for FABRIC**

Given the existent general equality in the feasibility table above, the most remarkable aspect is how the "Web Services" technology stands out when it comes to parameters such as implementation, cost or closeness to market. This fact is due to the nature of the solution, based on TCP/IP technologies broadly used in Internet implementations, which results in accessible, low-cost, well known resources. The specialization of the staff involved in the operations using this option is less demanding, as well, but this might be not such an important condition, considering that the scope of these agents (DSO and Energy Retailer) points to the internal staff of the companies, so proper training and skills are assumed.

Nevertheless, all solutions subject to analysis present key strong aspects:

- **Interoperability:** either thanks to its application over TCP/IP networks (Web Services), or their Smart Grid focus (ICCP, IEC61850), these technologies were designed with interoperability as a main goal, due to their application in environments where the interaction between large, complex subsystems is a must.
- **Security:** it depends on the WAN infrastructure strength, regarding cybersecurity, but the use of these protocols over Internet networks means that there exist a large variety of standard reliable solutions.
- **Safety:** the introduction of TCP/IP technologies in electrical systems implies the reduction of traditional copper wiring, which results in an increase of physical safety, thanks to the elimination of loaded cables and connections, replaced now by communication media.
- **Efficiency:** ICCP and IEC 61850 are defined with a methodology from services to protocol, which means that the latter adapt to the former, and not the other way round. They also have been used in scenarios where they have to coexist with legacy systems, which included low-performance hardware and communication media. This results in protocols where efficiency must be granted from their very definition. On its behalf, Web Services are based on text files carried out over broadband networks, so a good behavior in terms of efficiency is provided as well.

Apart from these four main points, a similar analysis can be carried out for the rest of the features addressed:

- **Implementation of the solution:** a hypothetical implementation of these technologies would be easy in the case of using Web Services, for they represent a consolidated,

broadly extended technology, deployed over TCP/IP networks. ICCP and IEC 61850 are more specific solutions, and thus require more expertise and particular tools or libraries.

- **Cost of the ICT tools:** for similar reasons as the one exposed in the previous paragraph, Web Services are also the alternative which fulfils this point in a better way. ICCP and IEC 61850 require relevant development work or licenses that are more expensive.
- **Maintenance:** a medium level of maintenance is required in the three cases, since they all are technologies subject to changes or updates.
- **Usability:** all of them are advanced technologies that require a relatively high knowledge from designers and engineers. Nevertheless, the usability provided to the final user depends on the implemented interfaces.
- **Closeness to market:** ICCP gets the higher evaluation here, for it is a solution oriented to the interaction of control centers, the case subject to study in this point. However, it cannot be said that Web Services or IEC 61850 are not oriented to market. In the first case, it is easy to find a large amount of services, in electrical networks or other sectors, implemented using this technology. IEC 61850, on its behalf, is one of the most relevant protocols used in the emerging Smart Grid deployments.

In short, it is safe to say that these three technologies fit in a scenario like the interaction required between the DSO and Energy Retailer systems, as well as the ones that shall be established with other platforms. Web Services may seem in a more advantaged position, because it is a more recent solution and, since it is composed of a set of TCP/IP protocols, its integration with existent systems and infrastructures should be easier. Anyway, ICCP and IEC 61850 are very serious candidates as well, given their orientation to electrical systems and Smart Grids. According to this, the following final evaluation is proposed:

- **Web services:** highly suitable for FABRIC.
- **ICCP:** suitable for FABRIC.
- **IEC 61850:** suitable for FABRIC.

In most of cases, the final decision shall depend strongly in the resources and related systems of the companies.

5. OVERALL SUMMARY OF THE ASSESSMENT

This final section of the document contains a summary of the assessment of the different technologies proposed, in terms of suitability for the implementation of the FABRIC system. It is important to highlight that this assessment does not imply a final selection for the implementation phase but a guideline of the technologies for each of them.

Table 26: Summary table of charging solutions

	Overall assessment
POLITO CWD WPT solution	**Suitable for FABRIC**
Saet Spa- Induction powered vehicle (IPV)	**Suitable for FABRIC**
Online Electric Vehicle (OLEV)	**Highly suitable for FABRIC**
Conductix Wampfler IPT	**Suitable for FABRIC**
Plugless Power	**Suitable for FABRIC**
Witricity	**Suitable for FABRIC**
Siemens eHighway (SCANIA)	**Not suitable for FABRIC**

Table 27: Summary table of ICT solutions

Technology group	**Technology**	**Overall assessment**
EMP[8]. Case 1: Basic Technologies. Service Bus	WSO2 ESB	**Highly suitable for FABRIC**
	Open ESB	**Suitable for FABRIC**
	ServiceMix	**Suitable for FABRIC**
EMP. Case 1: Basic Technologies. Process Management & Service Orchestration	Apache ODE	**Suitable for FABRIC**
	WSO2 Business Process Server	**Highly suitable for FABRIC**

[8] FABRIC Electric Mobility Platform

Technology group	Technology	Overall assessment
EMP. Case 1: Basic Technologies. Complex Event Processing	WSO2 CEP	**Highly suitable for FABRIC**
	Esper	**Suitable for FABRIC**
EMP. Case 2: Full Technologies	IBM Platform: IOC	**Suitable for FABRIC**
Identification	Barcode reader	**Not suitable for FABRIC**
	ANPR	**Highly suitable for FABRIC**
	RFID	**Suitable for FABRIC (Static recharge Scenario)**
	DSRC	**Highly suitable for FABRIC**
Routing	Google Maps Web services	**Suitable for FABRIC**
	Bing Maps	**Suitable for FABRIC**
	ARCGIS	**Suitable for FABRIC**
	HERE Maps	**Suitable for FABRIC**
	MapQuest	**Highly suitable for FABRIC**
Connected Car and HMI	MirrorLink	**Suitable for FABRIC**

Technology group	Technology	Overall assessment
	CarPlay	**Suitable for FABRIC**
	Open Automotive Alliance	**Suitable for FABRIC**
Charging Infrastructure Operator. Load Balancing	FABRIC implementation assessment	**Suitable for FABRIC**
Infrastructure Charging Control	ISO/IEC 15118	**Suitable for FABRIC**
	UNPLUGGED	**Suitable for FABRIC**
Charging Assistance	Magnetic	**N/A**
	Vision based	**N/A**
	DGPS based	**N/A**
Payment	Smart or Credit Card	**Highly suitable for FABRIC (especially for static scenarios)**
	Mobile	**Suitable for FABRIC**
	ETC	**Highly suitable for FABRIC**
Road Operator Modules/Interface	TRIDENT	**Not suitable for FABRIC**
	RADEF	**Not suitable for FABRIC**
	TRANSMODEL	**Not suitable for FABRIC**

Technology group	Technology	Overall assessment
	DATEX II	**Highly suitable for FABRIC**
DSO communication technologies	GSM/GPRS	**Suitable for FABRIC**
	M-Bus	**Suitable for FABRIC**
	WM-Bus	**Highly suitable for FABRIC**
DSO ICT technologies	Web Services	**Highly suitable for FABRIC**
	ICCP	**Suitable for FABRIC**
	IEC 61850	**Suitable for FABRIC**

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7. ANNEX I: LOAD BALANCING IN ELECTRIC VEHICLES CHARGING SOLUTIONS

7.1 Implementation methodology

Algorithmic approach

The load balancing module aims at allocating a shared power resource to multiple Electric Vehicles, in a manner that meets each vehicle's request for energy according to power supply availability, subject to constraints such as the local power limit, each vehicle's charging power limit and the cost of utilizing a particular power resource. Along with the minimization of the energy consumption cost, optimization criteria may also aim at improving power system quality, by reducing peak demands and by executing valley filling strategies. It should be noted that most approaches have a common characteristic; the Electric Vehicle's load is considered to be flexible, as effective charging time is usually less than idle parking time. This means that demand can be shifted in time, in order to maximize a pre-defined optimization objective. However this assumption is not necessary true during dynamic wireless charging, as sessions may last as much as 2-3 seconds. As FABRIC aims at a uniform assessment, for static, stationary and dynamic wireless charging environments, a review of approaches that target the load balancing problem in general will be presented and conclusions regarding the algorithmic feasibility of these approaches will follow.

If, load balancing is considered as a methodology that balances energy supply to demand and minimizes the total cost of consuming energy in order to charge a set of vehicles *N* during a time interval *T*, given constraints from the local charging installation power *Pinf*, the electric vehicle's maximum charging rate *Pn*, the required charging energy *Ereq,* then the problem to be solved in an analytical form is as follows:

$$minimize \sum_{t=0}^{T-1} c_t \sum_{n=0}^{N-1} p_{t,n}$$

$$subject\ to \sum_{t=0}^{T-1} DURATIONt * p_{t,n} \leq E_n\ , with \qquad p_{t,n} \leq \min\left(P_{inf}, P_n\right)$$

$$\forall\, n \in \{0, .., N-1\}$$

Where $\boldsymbol{p}_{t,\,n}$ represents the vector of power allocation to be determined for each vehicle *n*, ***c*** is the cost vector that reflects the weight of consuming an amount of power supply ***p*** at a timeslot ***t***. For instance, a common expression referenced in power system literature, for cost c, is the following quadratic cost function used for thermal generators:

$$C_t(p_t) = a_t p_t^2 + b_t p_t + c_t$$

Where $a_t, b_t, c_t \geq 0$.

Obviously the duration of each timeslot *t* defines the granularity of the optimization problem. For example if *DURATIONt=1h*, power shifts can be performed across hourly boundaries. If *DURATIONt* =1min, power shifts can be performed across minute boundaries, etc. The cost function could either represent the actual cost of energy or an artificial cost function used by the utility to control the load.

Multiple strategies have been put to action in order to solve the problem as it has been described in the aforementioned equations. They can be classified the following classes of algorithms; centralized and distributed. In the centralized approach, an aggregator collects the constraints and requests of EV's, charging infrastructure limits and the energy cost function and provides charging schedules back to EV's. In the distributed approach, each single charging agent (an entity responsible of calculating the charging sequence of a single electric vehicle, such as a smart meter or a vehicle ecu) optimizes its charging schedule in a manner that is both locally and system wise optimal.

The following paragraphs provide more details regarding both approaches.

Centralized approach

An algorithm for load balancing has been proposed by the European research project called PowerUp, [10], [11]. In this approach a deterministic load balancing algorithm, that dispatches power, required by electric vehicles that connect to a grid aggregator in order to be charged, was designed. The algorithm accounts for electric vehicle limitations, demands and grid inputs, like the forecasted power supply and price signal per timeslot and proposes a power supply schedule to each vehicle connected to the power grid. Scheduling is based on ranking timeslots according to the price signal provided by the energy utility and allocating power, timeslot by timeslot starting from timeslots of high priority, until the overall power allocation equals the Electric Vehicle's energy requirement. The algorithm is re-executed on the arrival of vehicles to be charged and can selectively cause the re-calculation of charging profiles of vehicles that are the process of charging, according to the priority of the request that initiates the execution of the algorithm. The algorithm's execution time is a linear function of the EV's participating in the scheduling procedure and of the total number of timeslots considered.

In [12], a deterministic algorithm for load balancing, referred to as, load dispatch algorithm is presented. The primary goal of this algorithm is to ensure that the aggregated power per timeslot, awarded to electric vehicles does not exceed the power threshold that has been allocated to the aggregator by the energy retailer during previously performed energy scheduling operations. Energy scheduling is done offline, 24h ahead of time, on the basis of statistical data of charging infrastructure usage. Then dispatch is performed online in a simple manner that aims at "enforcing" the initial energy scheduling and addressing individual charging requests. Such an approach decouples load scheduling from load dispatch (balancing) and thus

minimizes the overall amount of operations required during "online" or in real time, execution of the system. The approach for load dispatch in [12] and the approach for load balancing in PowerUp are similar, as they both aim at scheduling demand according to a price signal provided by the energy retailer and fulfilling electric vehicle and distribution system constraints. An additional parameter that has been taken into consideration in PowerUp is charging priority, which is used to classify various levels of charging requests in order to "privilege" the ones with higher priority. Such a mechanism could prove useful in cases where urgent charging is required and maximum supply should be available. (Charge ambulances etc...).

In [13] a three step approach for demand side management of plug-in hybrid electric vehicles is proposed. Within this framework, constraints and demands regarding power dispatch are transmitted by each electric vehicle (or charging post) to the charging station aggregator which in turn calculates the optimal, in terms of cost, charging profile, to be "shared" among the EV's. The sharing scheme is based on a common pricing signal that is calculated by the aggregator and distributed back to electric vehicles participating in the charging process. In this approach the optimization of energy planning is performed every time a vehicle plugs in to be charging. However the energy planning optimization is performed at an aggregator level and is decorrelated from the number of vehicles participating in the charging session. Therefore the execution time of the algorithm is not affected by the number of EV's participating in the charging session.

Load balancing has also been investigated in the SmartV2G European research program. The approach is targeted towards optimal management of charging stations by taking Demand Side Management (DSM) techniques and user preferences into consideration. According to the Smartv2G consortium, such an approach is essential in sustainable integration of electro mobility in the future electricity distribution grid, as mitigation of their impact on the grid, could be based on the optimal management of the charging requests. The SMARTV2G project, proposes a control system based on Model Predictive Control (MPC) theory, which optimally recomputes charge profiles for all the managed charging stations each time a new recharge starts, taking into account the current state of the grid, possible DSM orders received from the charging station controller by external agents (DSO, TSO/ Distribution System Operator), and the EV users preferences (final cost, charging time).

A detailed description of the MPC algorithmic approach has been reported in [14]. This approach targets aggregated charging control along a proper portion of the low voltage distribution grid. Results reported in [14], indicate that average processing time has been reported to be equal to 0.98s and maximum processing time 30.26 s for an average of 2823 vehicles. Such a computational performance seems to be acceptable within FABRIC for static and stationary charging. However it does not meet the real time characteristics of on-road dynamic wireless charging. To this extent, the possibility of reducing the average number of

managed vehicles in order to scale processing time down to acceptable levels for dynamic charging is a possibility.

Distributed approach

A distributed power scheduling approach based on game theory was proposed in [15]. A collaborative distributed algorithm that converges to a system wide optimal charging schedule is executed by each smart meter or electric vehicle charging controller. System optimality is achieved with respect to energy consumption cost. It is shown that energy consumption solutions are also very close to solving the minimization of the peak-to average load demand, thus reducing the effect of peak demands on the power network. In this case smart meters and charging controllers communicate through the local LAN in order to exchange control signals required by the algorithm. Such an architecture, aims at reducing aggregation levels in terms of energy planning optimization and easing large scale integration of electric vehicle charging agents.

[16] proposes a distributed framework for demand response and user adaptation in smart grid networks. The concept of congestion pricing in Internet traffic control is used to show that pricing information is useful to regulate user demand and balance network load. Based on this methodology, users or PHEVs can adapt their charging rates according to their preferences. In this approach the software components that are responsible of managing the charging process (charging agents), are connected to the grid supplier through an IP connection. Based on the pricing connection they receive from the grid, charging agents calculate the demand of next timeslot.

In [17] a strategy to coordinate charging of autonomous plug-in electric vehicles (PEVs) using concepts from non-cooperative games is developed. Each Plug-In Electric Vehicle reacts optimally with respect to a commonly observed charging trajectory y that is the average of all PEV strategies. This average is given by the solution of a fixed point problem in the limit of infinite population size. The ideal solution minimizes electricity generation costs by scheduling PEV demand to fit the overnight non-PEV demand “valley”.

Conclusion

FABRIC introduces dynamic on-road wireless charging in addition to well established modes such as static, and (less established) stationary charging. Dynamic charging may last as little as a couple of seconds depending on the vehicle speed and the length of the infrastructure, whereas static and stationary charging duration ranges from some minutes to hours. Most load balancing algorithms have been designed to take advantage of this flexibility in static and stationary charging, by exploiting techniques that are based on load shifting, i.e moving load from peak hours to off-peak hours, thus minimizing the overall cost of charging and reducing peak to average demand ratio. However this is not a possibility in dynamic charging. In this

case focus must be given in providing real time charging profiles to charging requests (centralized approach) or providing real time pricing data (distributed approach) to electric vehicles in order to support charging on the move that respects grid constraint's, maximizes the utilization of renewable energy resources and fulfils the EV's energy request. Therefore approaches such as the ones presented in [10], [12], [16] could be applied in FABRIC, in order to address the requirements of dynamic on-road charging. Examples of centralized load balancing (also referred to as direct load control in [18]) have been reported in [10], [12], whereas an example of distributed (or price/market based control [18]) has been reported in [16]. These two types of approaches have been identified in [18] as two advanced methodologies that could be used in order to avoid/postpone the need for additional generation capacity and fully exploit existing grid resources.

7.2 Communications

The load balancing module should encompass a communication interface to charging equipment, in order to receive Electric Vehicle charging parameters and transmit charging profiles back to EV's in centralized load balancing, or to ensure price and charging profile information exchange between the grid management module and charging agents, in case of distributed load balancing.

Standardized protocols such as ISO/IEC 15118 are being developed in order to support the whole charging sequence communication requirements in plug-in systems. Moreover metering protocols such as COSEM/DLMS 62056 and smart grid standards such as ISO/IEC 61850 support the use of standardized data objects that can carry charging session information in an interoperable and standardized way.

In FABRIC, the load balancing module will be embedded within the charging management system. This module could either establish a direct communication link to the Electric Vehicle or an indirect link supported by protocol mediation performed by the charging equipment. The following diagram depicts these approaches.

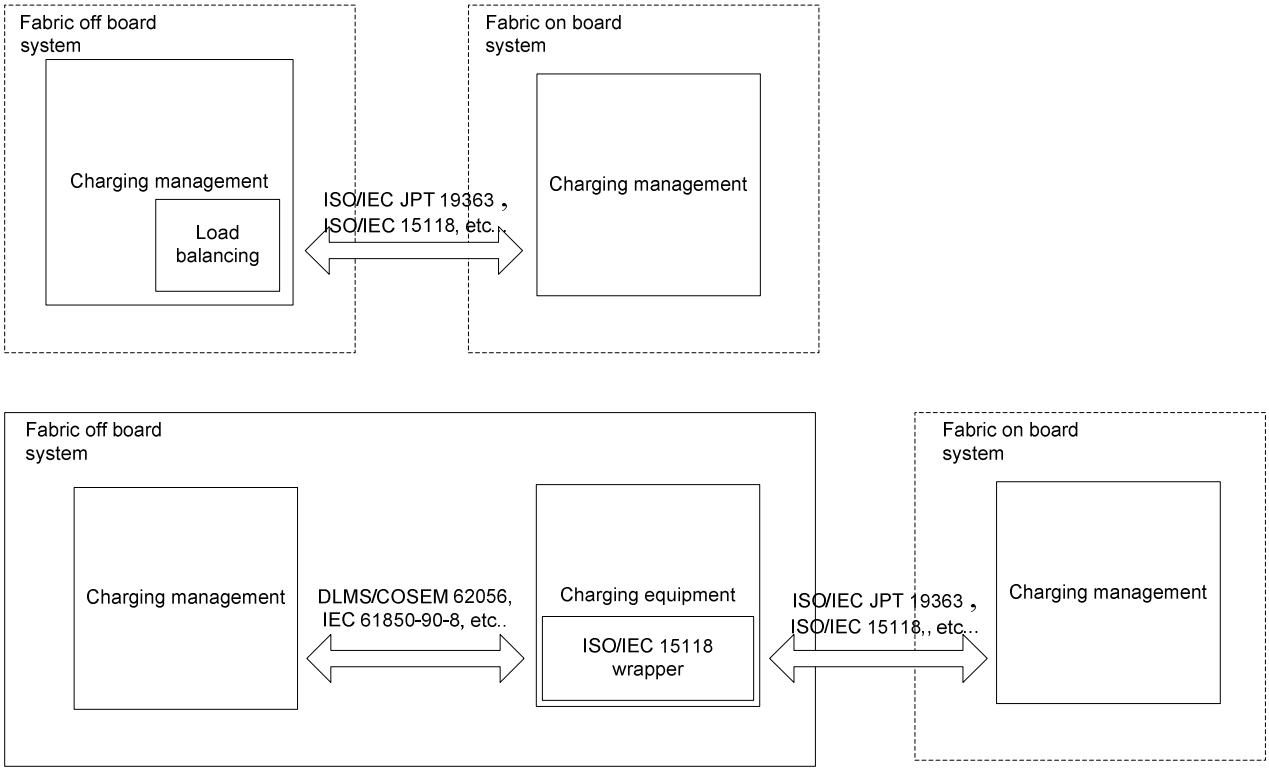

Figure 41: Load balancing communication architecture

The first approach implies that the charging management unit will directly communicate with the vehicle, through the use of a dedicated Electric Vehicle charging protocol. The second approach implies the introduction of a protocol mediation node that integrates smart grid related protocols such as DLMS/COSEM 62056, IEC 61850 with dedicated electric vehicle charging protocols such as, ISO/IEC 15118.

It is important to mention that thought ISO/IEC 15118 is tailored for conductive charging, definitions beyond OSI layer 3 (Network layer) could possibly be used in wireless charging COSEM/DLMS defines smart metering communication system for smart metering, whereas ISO/IEC 61850- “Communication networks and systems for power utility automation”, aims at providing a detailed communication model for various elements of the power system, targeting at measuring, monitoring, protecting and controlling the power flow. Moreover in 61850-90-8 object models for electric mobility are defined in order to fully describe the charging point and EV in terms of the power subsystem.

Reference architectures citing the aforementioned communication protocols have been reported by numerous European research programs. A brief presentation of these projects is made in the following paragraphs.

Integration of the DLMS/COSEM 62056 with ISO/IEC 15118 has been previously integrated and demonstrated in the PowerUp project [11]. Integration findings regarding the communication system have been reported in [19].

G4V, a European research program, aimed at surveying the impact on the grid from the mass introduction of EVs and proposed different charging strategies (centralised vs. decentralised approaches, simple vs. more sophisticated strategies), to review and analyse the available ICT solutions. For EV to charging point communications G4V proposes the use of ISO/IEC 15118.

SmartV2G, a European research program, aims at connecting the electric vehicle to the grid by enabling controlled flow of energy and power through safe, secure, energy efficient and convenient transfer of electricity and data. In [20], ISO/IEC 15118 is recommended for EV to charging point communications, whereas IEC 61850 is recommended for the distribution network automation.

Green e-motion, a European research program, proposes ISO/IEC 15118 and SAE J2293/2836/2847 as an example of a candidate solution for EV to charging station communications. Moreover the Open Charging Point Protocol is considered for charging station to charging management center communications [21].

OCPP is an open standard promoted by the Open Charge Alliance. OCPP focuses on the definition of technology independent communication services and transactions between the charging point and the charging management center [22].

Open source libraries of these protocols have been developed in order to support standardization and promote the use of these standards. These libraries could be adapted to be used within the FABRIC project.

- http://openv2g.sourceforge.net/ (IEC/ISO 15118)
- http://www.openmuc.org/jdlms-doc.html (DLMS/COSEM 62056)
- http://libiec61850.com/libiec61850/ (IEC/ISO 61850)
- http://www.openmuc.org/index.php?id=35 (IEC/ISO 61850, DLMS/COSEM 62056)
- http://www.ocpp.nl/node/16/release (OCPP Interface description between Charge Point and Central System FINAL)

The adoption of such open source libraries by FABRIC would greatly reduce the effort of developing and demonstrating a load balancing solution that will be interoperable, since it will ease communication interface design and development.

7.3 Execution platform

Within FABRIC, both static and dynamic wireless charging scenarios will be assessed. As analysed before, these approaches differ in terms of overall execution time and response

latency constraints. Dynamic charging duration could be as small as a couple of seconds for high vehicle speeds and short charging lanes, whereas static charging could last up to 8 hours or more. Therefore, in terms of load balancing execution performance, a solution based on deterministic response times and latencies is required. Real Time Operating Systems implement advanced scheduling techniques that guarantee task worst case execution times. In other words task execution is deterministic and its maximum duration is confined by an upper boundary.

Numerous RTOS open source solutions exist in both embedded and desktop oriented solutions such as

- https://www.rtai.org/ (Real Time Application Interface for Linux)
- http://www.rtems.org/ (RTEMS)
- https://rt.wiki.kernel.org/index.php/Main_Page (RT-Linux)
- http://www.freertos.org/

The adoption of an open source RTOS by FABRIC would greatly reduce the cost of developing and demonstrating software that enables load balancing.

7.4 Challenges and constraints

The load balancing module aggregates data from the grid interface and electric vehicles that are sharing common grid infrastructure in order to schedule charging sessions in a manner that ensures grid power quality, stability and at the same time ensures the quality of charging sessions. In order to meet these requirements the design and implementation of the load balancing module should overcome constraints regarding the communications and intelligence of the system. The design and implementation of the system should take the following constraints into consideration.

- Real time response to charging profile requests.
- Real time updating of current profiles when conditions change.
- Limited network bandwidth.

Real time response to charging profile requests requires minimization of latencies that occur in the communications network and during algorithmic processing. Moreover possibly limited network bandwidth requires an effective use of communication protocol messaging schemes in order to establish a real time and deterministic communication channel, between the load balancing module, electric vehicles and grid management entities. In order to overcome these constraints a detailed assessment of applicable communication technologies, protocols and algorithms will be made as defined by the FABRIC DoW in WP23, WP33. Detailed specification that will guide the design of the load balancing module will follow in WP24, WP34.

7.5 Development of subsystems related to the load balancing module.

As seen in Section 4.6, the load balancing controller is a part of the charging management module that will be interfaced with the grid management module which in order to establish a direct communication link with smart grid entities such as the DSO or the Energy retailers. Since power supply information is essential to load balancing, the interface between these modules should be designed in a manner that ensures consistent and fast information exchange, in order to avoid inserting another source of latency in the system. Moreover the load balancing module could be either directly interfaced to the Electric Vehicle or may be indirectly interfaced through a protocol mediation layer. In the latter case, an efficient and fast protocol mediation mechanism should be designed, implemented and tested in order to guarantee that the latency added to the system does not prohibit a charging profile response within time boundaries.

7.6 Load balancing module improvement proposal

As previously presented, load balancing can be considered as a generic optimization problem. Either centralized or distributed architectures have been proposed to address load balancing. The core logic of these architectures is mainly based on dynamic programming algorithms, linear programming algorithms or distributed game theory based algorithms. In order to choose the best among centralized or distributed load balancing it is necessary to assess various algorithmic approaches in order to determine which one suits the problem mainly in terms of execution time and optimality. Moreover a detailed assessment of the suitability of existing smart grid and EV charging communication protocols to a centralized or distributed load balancing architecture must be made in order to ensure the design an interoperable solution within FABRIC.

8. ANNEX II: OTHER CAR CONNECTION SOLUTIONS

Here it is described other solutions that are less important in the automotive industry.

8.1 Ford Sync

Figure 42: Sample screens for Ford Sync technology

This is the solution created by Ford in collaboration with Microsoft in the year 2007. This system allows users to make hands-free telephone calls, control music and perform other functions with the use of voice commands. Also the users can download information from your phone and play some applications that are create for this system as Pandora Radio or Stitcher Radio.

Main features:

- Mobile integration allows the user transfer of contacts between a mobile phone and the on-board phone book; also the user can execute phone calls, conference call, and control the phone battery charge.
- Audible SMS, the system can read and write SMS with voice command system.
- Digital Music player support: the system can connect to popular digital music players via Bluetooth or a USB connection. Users can browse through music collections by genre, album, artist, and song title using voice commands.

8.2 Windows Embedded Automotive

Figure 43: Sample screens for Windows Embedded Automotive

Windows Embedded Automotive is an embedded operating system based on Windows CE to be used on computer systems in automobiles. The first automotive product built by Microsoft's Automotive Business Unit debuted on December 4, 1998 as the AutoPC, and also includes Ford Sync, Kia Uvo, and Blue&Me. Microsoft's Automotive Business Unit has built both the software platforms used for automotive devices as well as the devices themselves.

8.3 QNX

Figure 44: Sample screens for QNX

QNX is a commercial Unix-like real-time operating system, aimed primarily at the embedded systems market. The product was originally developed in the early 1980s by Canadian company Quantum Software Systems, later renamed QNX Software Systems and ultimately acquired by BlackBerry in 2010. QNX was one of the first commercially successful microkernel operating systems and is used in a variety of devices including in-car infotainment and control systems.

9. ANNEX III: ADDITIONAL INFO ON DSO AND RETAILER MODULES INTERFACE

9.1 Use case overview for DSO Interface

The use cases under “DSO Interface” responsibility are shown next, grouped by functional blocks, as stated in the previous section. However, the preliminary definitions contained in this list may be explained in a more detailed way or modified by other work packages technical developments.

- **Energy management:** this subsystem takes charge of the real-time operation and control related to the energy flow. A division must be made between the VE charging infrastructure itself and the necessary coordination with the general grid operation and activities regarding maintenance or outages.
    - **Commands generation:** the DSO might have the ability to send orders to the retailer, in order to increase or decrease the energy amount dedicated to the EV charge, in order to react to grid necessities or incidents.
    - **Commands monitoring:** the result of the actions unleashed by the previous commands might be monitored, obtaining information about their fulfilment and the effect of the response.
    - **EV resources monitoring:** real-time information about energy consumption by the on-road charging systems and their state. These data shall serve as input for other subsystems and use cases.
    - **Infrastructure monitoring:** real-time monitoring and acquisition of information about the state of the grid, from an electrical point of view.
    - **Outage and limitation management:** the retailer shall be informed about eventual incidents in the grid (outages or supply restrictions).
- **Grid management:** apart from the administration of the grid facilities, it includes activities such as planning of demand and supply.
    - **Demand:** according to the state of the grid, the EV on road charge supply shall be managed, communicating to the retailer the modifications to perform when needed.
    - **Validation:** interaction between the DSO and the retailer in order to carry out a cooperative and periodic planning and validation of the energy sold to the latter.
    - **Maintenance and development:** management of updated information about the condition of the EV charging infrastructure, keeping record of the state of the facilities and the maintenance operations, if any.
- **Measurements:** management of the magnitudes related to the operation of EV charging.

  - **Real-time demand:** acquisition of EV charging demand data, in a periodic way or on DSO demand.
  - **Real-time supply capacity:** acquisition of EV charging supply capacity, in a similar way as in the previous case.
  - **Real-time storage capacity:** if storage systems to assist on-road EV charging are available, their capacity and state shall be monitored.
- **Economic system:** interaction with other external systems to obtain, provide or share the information about energy rates or dynamic prices.
  - **Pricing management:** exchange between the DSO and the Retailer of information regarding energy rates. Dynamic prices might be used in order to encourage demand management or demand curve flattening.

9.2 Use case overview for Energy Retailer

As found in Section 4.11.2.2, a first sight to the use cases which shall be in charge of the "Energy retailer interface" agent is shown next. This list is, at this phase of the project, subject to further developments of FABRIC work packages.

- **Price management:** this subsystem performs the rate negotiation with the DSO, as well as the management of the associated interaction with the users or clients. Incentives in order to encourage demand control may be applied. The acquisition of demand data takes place here, in order to keep record of their evolution, which may be applied in the calculation of the prices offered to the consumer.
- **Purchase and sale:** connected to the information managed in the previous subsystem, it takes charge of the execution of the purchases and sales. It keeps a data base with the data associated to every transaction.
- **Quality management:** data base keeping track of the quality service offered to the users. It may consider information regarding grid operation or state and client attention.
- **Roaming:** on-road EV charging may cause important needs of managing roaming (i.e. one particular client using resources from a supplier different than his), in case of future market organization advises it. The data bases associated to this subsystem shall manage user information, as well as geographical location data.
- **Access control and user authorization:** a data base with user information shall be managed, in order to carry out a proper control to the access to the on-road EV charging resources.
- **Client attention:** access point for the client for all interaction needs with the energy retailer. It shall have clearance to the information managed by other subsystems, in order to solve user's queries or complaints.

9.3 Additional information on Web Services

9.3.1 SOAP: Simple Object Access Protocol

SOAP is a communication protocol between applications which does not depend on either the platform or the programming language. It defines the XML format for the messages exchanged in a Web Service and relies on other application layer protocols like HTTP and SMTP. This protocol has advantages over other legacy protocols, like CORBA or DCOM:

- **Interoperability.**
- **Security.**
- **Simplicity.**

A SOAP message consists of a XML document containing the following four elements:

- **Envelope:** identifies the XML document as a SOAP message.
- **Header:** contains additional information.
- **Body:** contains call and response information.
- **Fault:** provides error handling.

An example of a SOAP request:

```
POST /InStock HTTP/1.1
Host: www.example.org
Content-Type: application/soap+xml; charset=utf-8
Content-Length: nnn


<?xml version="1.0"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2001/12/soap-
    envelope" soap:encodingStyle="http://www.w3.org/2001/12/soap-
    encoding">
<soap:Body xmlns:m="http://www.example.org/stock">
<m:GetStockPrice>
    <m:StockName>IBM</m:StockName>
</m:GetStockPrice>
</soap:Body>

</soap:Envelope>
```

Figure 45: Example of SOAP request

And an example of a SOAP response:

```
HTTP/1.1 200 OK
Content-Type: application/soap+xml; charset=utf-8
Content-Length: nnn


<?xml version="1.0"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2001/12/soap-
    envelope" soap:encodingStyle="http://www.w3.org/2001/12/soap-
    encoding">
<soap:Body xmlns:m="http://www.example.org/stock">
    <m:GetStockPriceResponse>
        <m:Price>34.5</m:Price>
    </m:GetStockPriceResponse>
</soap:Body>

</soap:Envelope>
```

Figure 46: Example of SOAP response

9.3.2 WSDL: Web Service Description Language

It is necessary to define rules in order to enable the communication between two systems. The WSDL is an interface definition language, defined in a XML file, which provide a machine-readable description of the Web Service. This XML document specifies how one application can request data from another system, what parameters it expects and the data structures it returns.

The WSDL XML file consists of the following elements:

- <types>: a container for data type definitions used by the Web Service.
- <message>: a typed definition of the data being communicated.
- <operation>: an abstract description of an action supported by the service.
- <portType>: a set of operations supported by one or more endpoints.
- <binding>: a protocol and data format specification for a particular port type.
- <port>: a single endpoint defined as a combination of a binding and a network address.
- <service>: a collection of related endpoints.

An example of a WSDL file:

```
<message name="getTermRequest">
    <part name="term" type="xs:string"/>
</message>
<message name="getTermResponse">
    <part name="value" type="xs:string"/>
</message>
<portType name="glossaryTerms">
    <operation name="getTerm">
        <input message="getTermRequest"/>
        <output message="getTermResponse"/>
    </operation>
</portType>
```

Figure 47: Example of WSDL file

9.3.3 UDDI: Universal Description, Discovery and Integration

UDDI is a directory to register and locate Web Services. UDDI is a platform-independent framework for describing services, discovering businesses, and integrating business services by using the Internet, i.e. a directory to register and locate Web Services.

UDDI is a directory of Web Service interfaces, described by WSDL, and which communicates via SOAP. Its main advantages are the following:

- Makes it possible to discover the right business from all of them currently online.
- Defines how to enable commerce once the preferred business is discovered.
- Reaches new customers and increases access to current customers.

- Expands offerings and extending market reach.
- Solves customer-driven need to remove barriers to allow for rapid participation in the global Internet economy.
- Describes services and business processes programmatically in a single, open and secure environment.

9.3.4 Architecture

The following figure illustrates the architecture of Web services:

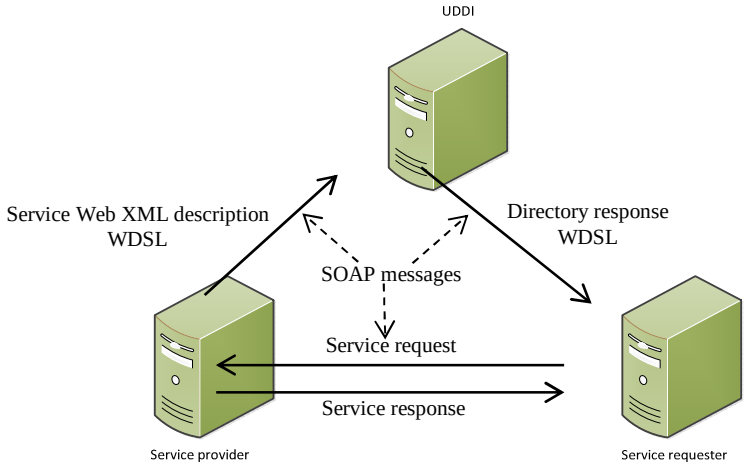

Figure 48: Example of Web service architecture

The service provider sends the Service Web description in a WSDL file to UDDI. The service requester contacts UDDI to find out the provider for the data it needs and then, it contacts the service provider using the SOAP protocol. The service provider validates the service request and sends structured data in an XML file, using SOAP.

A Web Service is a technology with great potential which enables servers to communicate to each other thanks to the provision of interoperability between platforms and the use of open protocols.

9.4 Additional information on ICCP

9.4.1 Architecture

ICCP maximizes the use of existing standard protocols in all layers in the OSI reference model. This requires the development of a new protocol for ICCP only in the upper sublayer of layer 7.

The protocol stack used by ICCP is the standard UCA Version 1.0 profile with control center application at the top.

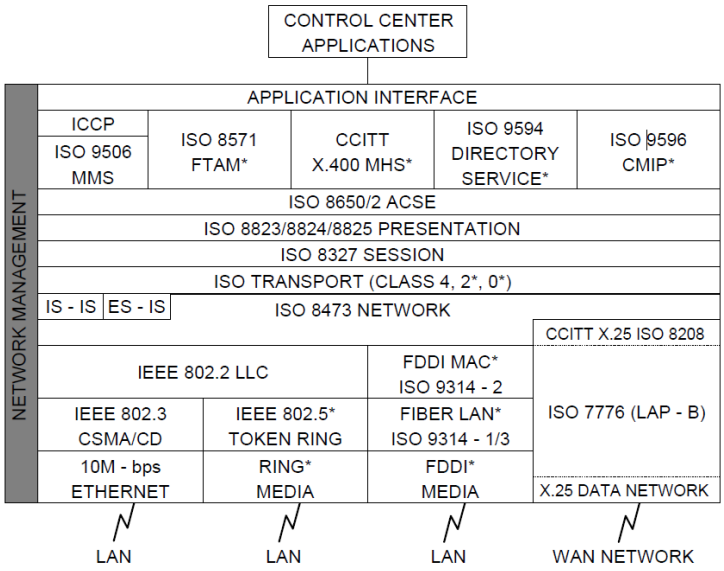

Figure 49: ICCP architecture

ICCP specifies the use of Manufacturing Messaging Specification (MMS) for the messaging services needed. MMS specifies the mechanics of naming, listing and addressing variables, and of message control and interpretation, while ICCP specifies such things as the control center object formats and methods for data requests and reporting. Applications at different control centers, written by different vendors, may interoperate to share data, control utility devices and output information messages.

Because of the protocol architecture, ICCP is independent of the lower layers and shall operate over them with only configuration changes.

ICCP is based on client / server model. All data transfers originate with a request from a control center (the client) to another control center which owns and manages the data (the server). A control center may function as both a client and a server.

There are various services provided in ICCP to accomplish data transfers, depending on the type of request. If the client makes a one-shot request, the data will be returned as a response. However, the client shall enable the reporting mechanism when it makes a request for periodic transfer of data, or transfer of data as an unsolicited report only when trigger conditions are satisfied.

ICCP uses the ISO Association Control Service Element (ACSE) to establish logical associations. Multiple associations may be established from a client to multiple different control center servers. In the same way, multiple associations may be established to the same control center for the purpose of providing associations with different Quality of Service.

Object model concepts are used in two different ways in ICCP. First, all ICCP services are provided via ICCP server objects which may be thought of as classical objects with data

attributes and methods as defined in object-oriented design methodologies. There are two basic types of methods in ICCP called operations and actions. An operation is client-initiated via a request to a server. An action is a server-initiated function. Second, all other data and control elements typically exchanged between control centers are defined as “data object”.

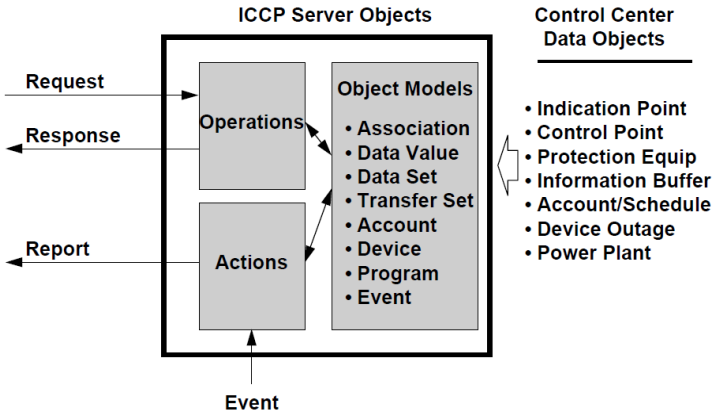

Figure 50: ICCP Server Objects

For these server objects, conformance blocks are defined as a way of grouping ICCP objects together to provide fundamental types of services. Nine conformance blocks are defined for data objects as a way of specifying which server object services are needed to transfer each data object.

9.4.2 Server objects

9.4.2.1 Association objects

Association objects are used to establish a logical connection between two ICCP instances. Three operations are defined for Association objects:

- **Associate:** operation used by a client to connect to a server.
- **Conclude:** operation used by either a client or a server to provide an orderly termination to an association (e.g. for some planned maintenance).
- **Abort:** operation used by either a client or a server to terminate an association when there are failures in the underlying communication mechanisms.

9.4.2.2 Data Value objects

Data value objects represent real-time data values such as analog measurements, digital status, control points or data structures. There are four operations defined for Data Value objects:

- **Get Data Value:** operation used to request the value of a single point.
- **Set Data Value:** intended to permit a data value to be written or set at a local control center by a remote control center. In practice, this is not usually permitted.

- **Get Data Value Names:** allows a client to obtain a list of the names of the entire Data Value object at a remote control center for which that client has permission.
- **Get Data Value Type:** allows a client to obtain the type attribute for Data Value object.

9.4.2.3 Data Set objects

Data Set objects are ordered lists of Data Value objects maintained by an ICCP server. The Data Set object can be used by a client to remotely define a list of points to be reported as a group. Generally, real-time data exchange in control centers groups the data values according to some features, such as type, refresh time, access permission, etc.

There are six operations defined for Data Set objects:

- **Create Data Set:** allows a client to create a Data Set object at a remote server. The client can specify the following parameters to be included in a Transfer Report: Transfer Set name, Data Set Conditions Detected, Event Code detected or Transfer Set Time Stamp.
- **Delete Data Set:** allows a client to delete a previously defined Data Set object.
- **Get Data Set Element Values:** allows a client to obtain the value of each Data Value objects included in the referenced Data Set object.
- **Set Data Set Element Values:** allows a client to set the value of each Data Value objects included in a Data Set. In practice, this is not usually permitted.
- **Get Data Set Names:** allows a client to get the names of all the Data Set objects currently defined at a server.
- **Get Data Set Element Names:** allows a client to obtain a list of names of the entire Data Value object currently included in a specific Data Set object at a server.

9.4.2.4 Transfer Set object

Transfer Set objects residing at an ICCP server are used by an ICCP client to establish the actual transfer of data values. The transfer of groups of data defined in Data Set objects requires the use of a Transfer Set. The exchange of most all other data in ICCP requires a Transfer Set to be established first.

The Transfer Set object permits information to be exchanged on a periodic basis, on change of state or value, in response to a particular sever event, or on operator request.

There are four Transfer Set Object Models:

- **Data Set Transfer Set:** used for establishing the transfer of Data Sets defined and created using the Data Set object.
- **Time Series Transfer Set:** used for transferring the data values of a single Data Value object at different incremental times as specified by a delta time interval.

- **Transfer Account Transfer Set:** used for transferring many different types of data objects. Account is a generic term to represent information on schedules, device outages, curves and other entities used by control centers which have in common the use of complex data structures to represent data.
- **Information Message Transfer Set:** used for transferring the Information Buffer data object which is intended for sending unstructured ASCII text strings or binary data.

There are four operation defined for Transfer Set objects:

- **Start Transfer:** permits a client to request a server to begin to transfer data under the conditions specified by the client in this operation.
- **Stop Transfer:** used by a client to stop a data transfer operation. A new Start Transfer operation is required to once again enable the transfer.
- **Get Next Data Set Transfer Set Value:** used by the client as the first step in starting a Data Set data transfer since the server maintains a “pool” of available Data Set Transfer Sets for a client to use.
- **Get Next Time Series Transfer Set Value:** is used for starting the reporting of a series of values time evolving.

9.4.2.5 Program object

A Program object provides a client with remote operation of a program at a server site. The actual program being controlled can be any application program at the server site.

There are six operation defined for Program objects:

- **Start:** starts an IDLE program.
- **Stop:** stops a running program.
- **Resume:** starts a stopped program.
- **Reset:** IDLEs a stopped program.
- **Kill:** makes a program unrunnable.
- **Get Program Attributes:** returns information on a running program.

9.4.2.6 Event object

An event object represents a system event at a server site, such as a device changing state or the occurrence of a certain data error. There are two objects associated with events:

- **Event Enrolment:** permits a client to express interest in being notified of particular event when it occurs at a server site.
- **Event Condition:** objects predefined at a server for all system events that are to be available to clients for enrolment.

9.4.2.7 Conformance Blocks

ICCP was designed from the beginning to be modular. Each conformance block represents a specific function or set of functions which are available to the user. Each control center shall specify which blocks need to implement.

There are nine blocks available in ICCP:

- **Block 1:** provides periodic transfer of power system data. It is the minimum that a developer can implement and that a user can purchase. This block enables de exchange of the following type of data: status points, analog points, quality codes, time stamps and protection equipment events.
- **Block 2:** provides reporting by exception that is more bandwidth efficient. Report by exception allows the client to specify that power system objects shall be reported only when a change is detected or when an integrity check is performed.
- **Block 3:** block data with report by exception is a very efficient transfer mechanism under certain conditions. It is more efficient than block 2 due to low data rates.
- **Block 4:** information messages. The use of this service might be for a utility to notify other utilities, within its interconnection, that an event more complex than that represented by simple power system data values has occurred, e.g. request for emergency use of pool reserves.
- **Block 5:** device control. This block provides a mechanism for transferring a 'request to operate a device' from one ICCP implementation to another. ICCP does not directly control the device, rather it communicates a client's request to operate a device to the server.
- **Block 6:** remote program control. This block provides a mechanism for an ICCP client to perform program control at a server ICCP implementation site. Program control is only available by prior agreement between any two ICCP sites. Implementation of program control is made very straight forward by the fact that MMS provides program invocation and control as part of its basis services.
- **Block 7:** event reporting. This block adds the Event Enrolment and Event Condition objects. It is not required for any of the other blocks, but instead provides extended reporting of system events occurring at a remote site.
- **Block 8:** additional user objects related to transferring scheduling and accounting information, device outage information and power plant information.
- **Block 9:** provides an ICCP client with the ability to receive time series data. Time series data might be data that has required sampling time too fast to conveniently transfer it continuously between ICCP implementations, and is not needed at the client site in real time. For example, sampling data on key analog values on the backbone transmission system during a disturbance.

9.4.2.8 Communication link requirements

A data channel with a minimum rate of 64 kbps is required for the implementation of an ICCP link, over a satellite, optical fiber or copper wired medium. The delay in the channel shall be verified to be less than one second, especially in satellite links.

Two channels over different mediums are recommended to get the required redundancy according to the importance of real-time information.

9.5 Additional information on IEC 61850

9.5.1 Data model

The data model defined in the IEC 61850 provides a description of the real world. This model is a representation of physical devices (switches, breakers, transformers, etc.) with all their properties.

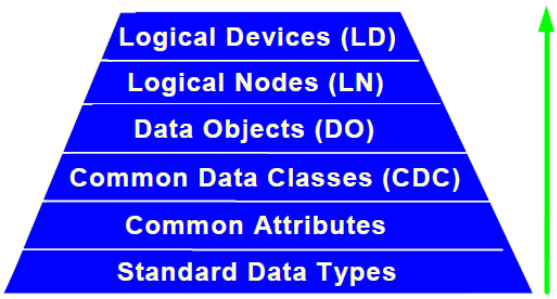

Figure 51: Data model hierarchy

To represent any element in the systems, the following categories are taken into account:

- **Base DC:** Basic data attribute types (boolean, integer, float, etc.).
- **Comp. DC:** composed data attribute types (Quality, Timestamp, etc.).
- **CDC:** common data class for logical node composition.
- **Logical nodes (LN):** abstract representation of a substation automation functionality, divided in the following groups:
  - **Group L:** system logical nodes.
  - **Group P:** nodes for protection functions.
  - **Group R:** nodes for protection related functions.
  - **Group C:** nodes for control.
  - **Group G:** nodes for generic references.
  - **Group I:** nodes for interfacing and archiving.
  - **Group A:** nodes for automatic control.
  - **Group M:** nodes for metering and measurement.
  - **Group S:** nodes for sensors and monitoring.
  - **Group X:** nodes for switchgear.

- **Group T:** nodes for instruments transformers.
- **Group Y:** nodes for power transformers.
- **Group Z:** nodes for further power system equipment.

- **Logical device (LD):** virtual device consists of several logical nodes.

The following example defines a logical node which represents a current transformer. Its attribute Amp (instantaneous current value) is a CDC of SAV class. This class consists of a set of attributes. The sVC attribute consists of the attributes scaleFactor and offset. Each one is a base DC (FLOAT32).

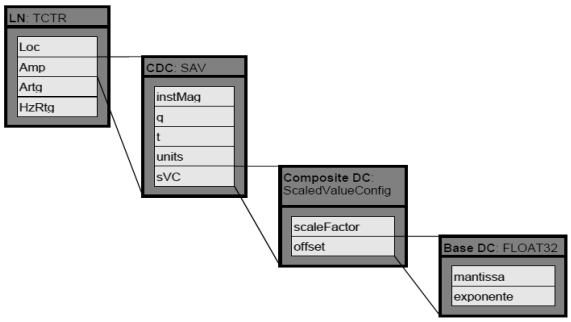

Figure 52: Example of logical node

This data model is what provides to the standard its powerful features in the field of electrical distribution.

9.5.2 Services

The IEC 61850 standard defines abstract classes and services such that the specifications are independent of specific protocol stacks, implementation and operating systems. It is intended to provide interoperability between a variety of substation and feeder devices. Communication between devices is achieved by the hierarchical data classes and services provided by these classes.

The standard defines the abstract communication service interface (ACSI) for use in the utility substation domain that requires real-time cooperation of intelligent electronic devices.

Abstract services describe communication between a client and a remote server for:

- real-time data access and retrieval,
- device control,
- event reporting and logging,
- publisher/subscriber,
- self-description of devices,
- data typing and discovery of data types, and
- file transfer.

Moreover, the standard defines abstract services for fast and reliable system-wide substation event distribution between an application in one device and many remote applications in different devices and for transmission of sampled measured values minimizing the time between sampling and transmission.

These are the ACSI service models and services defined in IEC 61850:

Table 28: ACSI service models and services defined in IEC 61850

Service model	Description	Services
Server	Represents the external visible behavior of a device. All other ACSI models are part of the server.	ServerDirectory
Application association	Provision of how two devices can be connected. Provides different views to a device: restricted access to the server's information and functions.	Associate Abort Release
Logical device	Represents a group of functions; each function is defined as a logical node.	GetLogicalDeviceDirectory
Logical Node	Represents a specific function of the substation system, for example, overvoltage protection.	GetLogicalNodeDirectory GetAllDataValues
Data	Provides means to specify typed information, for example, position of a switch with quality information, and timestamp.	GetDataValue SetDataValue GetDataDefinition GetDataDirectory
Data set	Allows to group various data together.	GetDataSetValues SetDataSetValues CreateDataSet DeleteDataSet GetDataSetDirectory
Substitution	The client can request the server to replace a process value by a value set by the client, for example, in case of an invalid measurement value.	GetDataValue SetDataValue
Setting group control	Defines how to switch from one set of setting values to another one and how to edit setting groups.	Select ActiveSG SelectEditSG

		SetSGValues ConfirmEditSGValues GetSGValues GetSGCBValues
Reporting and logging	Describes the conditions for generating reports and logs based on parameters set by the client. Reports may be triggered by changes of process data values or by quality changes. Logs can be queried for later retrieval. Reports may be sent immediately or deferred (buffered).Reports provide change-of-state and sequence-of-events information exchange.	Buffered RCB: Report GetBRCBValues SetBRCBValues Unbuffered RCB: Report GetURCBValues SetURCBValues Log CB: GetLCBValues SetLCBValues QueryLogByTime QueryLogAfter GetLogStatusValues
Generic substation events (GSE)	Provides fast and reliable system-wide distribution of data; peer-to-peer exchange of IED binary status information. GOOSE (Generic Object Oriented Substation Event) supports the exchange of a wide range of possible common data organized by a dataset.	GOOSECB: SendGOOSEMessage GetGoReference GetGOOSEElementNumber GetGoCBValues SetGoCBValues
Transmission of sampled values	Fast and cyclic transfer of samples, for example, of instrument transformers.	Multicast SVC: SendMSVMessage

		GetMSVCBValues SetMSVCBValues Unicast SVC: SendUSVMessage GetUSVCBValues SetUSVCBValues
Control	Describes the services to control, for example, of instruments transformers.	Select SelectWithValue Cancel Operate CommandTermination TimeActivatedOperate
Time and time synchronization	Provides the time base for the device and system.	TimeSynchronization
File transfer	Defines the exchange of huge data blocks such as programs.	GetFile SetFile DeleteFile GetFileAttributeValues

From all of these services, reporting and control are taken into account for this project.

9.5.3 Service mapping over communication protocols

The objects represented by the data model and the services shall be mapped in communication protocols to be transmitted through the network. Mapping is intended to provide inter-device operation of a variety of substation and feeder devices to achieve interoperability, providing detailed information on how to create and exchange concrete communication messages that implement abstract services and models.

There are different kinds of messages: Fast messages, trip messages, medium speed messages, low speed messages, raw data, file transfer functions and time synchronization messages. Depending on their requirements, they shall be mapped in different protocols.

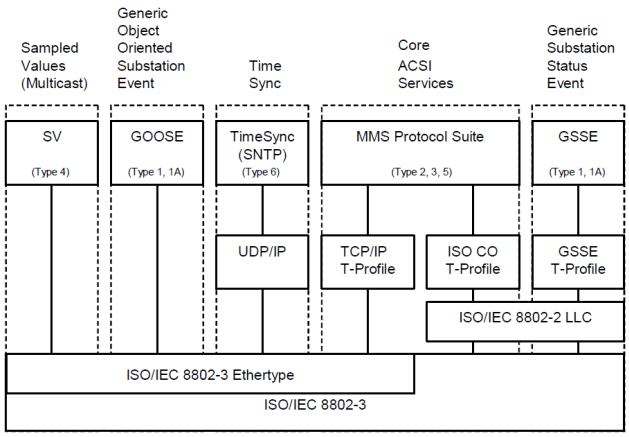

Figure 53: Service mapping

Sampled Values (SV) protocol is used for measures transmission. SV is a link layer protocol to transmit measures over a multicast communication.

GOOSE (Generic Object Oriented Substation Event) is the protocol used to transmit events between IEDs. GOOSE is a link layer protocol for fast and reliable event transmission over a multicast communication.

Most of services are mapped on MMS (Manufacturing Message Specification) protocol. This protocol represents the core of the standard. It specifies processes and services needed to exchange information between devices. The services mapped on this protocol are alarm reporting, command execution (control), object self-description or file transfer over a client-server architecture and using the following protocol stack.

Table 29: Standards referenced in MMS (Manufacturing Message Specification) protocol

Application	**Association Control Service Element (ACSE) – ISO 8649/8650**
Presentation	Connection Oriented Presentation – ISO 8822/8823 Abstract Syntax Notation (ASN) – ISO 88214/8825
Session	Connection Oriented Session – ISO 8326/8327
Transport	ISO transport over TCP – RFC 1006 Transmission Control Protocol (TCP) – RFC 793
Network	Internet Control Message Protocol (ICMP) – RFC 792 Internet Protocol (IP) – RFC 791 Address Resolution Protocol (ARP) – RFC 826

Link	IP datagrams over Ethernet – RFC 894 MAC – ISO 8802-3 [Ethernet]
Physical	Ethernet

According to the scope of this project, reporting and control services are taken into account, both of them mapped over MMS protocol.

9.5.4 Report

Reporting service provides mechanisms for transferring data values caused by well-defined conditions from a logical node to one client. This service sends timely reports which serve as an indication to clients under real-time constraints. This transmission minimizes the network bandwith impact sending reports only when required and providing low-frequency integrity scan and client-initiated general interrogation.

Reporting provides mechanisms to report packed values of data instances immediately or after some buffer time. In this way, several retrieval schemas are provided:

- Change-of-state notification of clients: immediate reports.
- Sequence-of-events: keeping reports in sequence.
- Polling data at any time.

The procedures required for reporting values from logical nodes to one client are defined in the Report Control Block (RCB). Instances of report control are configured in the server at configuration time. The server restricts access to an instance of a report control to one client at a time.

There are two classes of report control defined:

- **Buffered Report Control Block (BRCB),** where internal events issue immediate sending reports or buffer the events for transmission, such that data values are not lost due to transport flow control constraints or loss of connection. BRCB provides the sequence-of-events functionality.
- **Unbuffered Report Control Block (URCB),** where internal events issue immediate sending of reports on a “best efforts” basis. If no association exists, events may be lost.

Events which cause report generation are defined in the trigger conditions:

- **Data-change (dchg):** a report entry shall be generated due to a change of the value of the data attribute.
- **Quality-change (qchg):** a report entry shall be generated due to a change of the value of the quality attribute.
- **Data value update (dupd):** a report entry shall be generated due to updating the value of any attribute.

- **Integrity:** a report shall be generated each time the integrity period has expired.
- **General interrogation:** a report shall be generated on demand of the client.

The reporting service is used to report alarms, signaling and telemetering.

9.5.5 Control model

This is a service to control devices by executing commands. The control service provides a specific way to change the state of internal and external processes by a client. The control model can only be applied to data object instances of a Controllable Common Data Class (CDC). These objects are referred to as “control objects” and represent real objects.

Four control models are defined:

- **Direct control with normal security.**
- **SBO (Select Before Operate) control with normal security.**
- **Direct control with enhanced security.**
- **SBO control with enhanced security.**

In control models with SBO, the client selects the object before operate on it, avoiding any other clients to control the object.

In control models with enhanced security, the control shall end with a command termination. Control with enhanced security should be used for control procedures that cause an important action outside the device containing the accessed control object.

The control service uses a client – server architecture and is mapped on the MMS protocol. Basically consist of the execution of the MMS read (select) and write (operate) services of controllable objects with FC = SP and FC = CO.

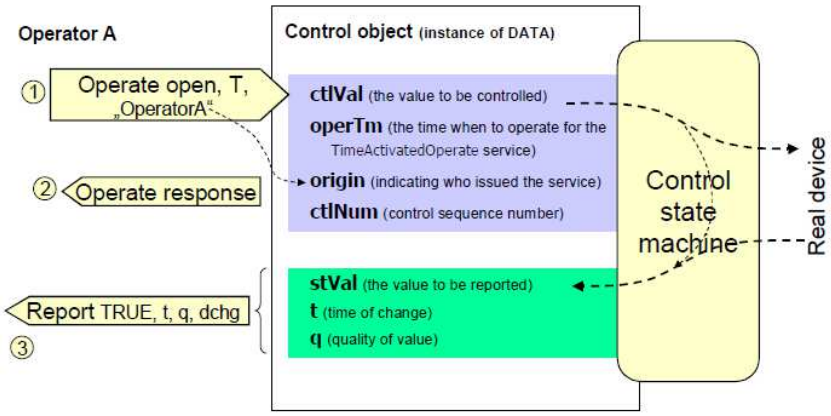

Figure 54: Control model scheme

9.5.6 Device and installation configuration

One of the most innovative aspects of the IEC 61850 standard is the definition of a complete configuration language. Because of its ability to structuring, the XML language is used to define a SCL file with the description of the installation.

The SCL file describes the system in the sense of the single line diagram, the IEDs for general and specific functions and the complete configuration of all the IEDs mapped to its elements and processes. The file contains three sections: a section with the functional specification of the substation or the electric structure, the IEDs specification and the communication structure.

There are different types of file, all of them are a particularization of the SCL file:

- **SSD (System Specification Description):** single line diagram of the installation and logical nodes.
- **ICD (IEC Capability Description):** describes the IED features. It contains the data templates, types of data and logical nodes implemented by the device.
- **SCD (Substation Configuration Description):** contains all the IEDs, a configuration section and a substation section.
- **CID (Configured IED description):** is a SCD file for an only IED which is downloadable in a specific IED.

In conclusion, IEC 61850 is a powerful standard which provides interoperability due to the standardization of the communications and data model. It uses the advantages of the new automation technologies and communications implying a reduction of the design, operation and maintenance cost. The IEC 61850 has been adopted as a worldwide standard and accepted by both manufacturers and users. Furthermore, it has been extended to define other standards such as hydroelectric plants, wind farms or distributed generation, making it one of the most important protocols used in Smart Grids.

9.6 Additional information on ICT security aspects

9.6.1 Attacks

When working with confidential information is important to know the kinds of attack to which the information is exposed to protect it:

- **Interruption:** part of the system becomes lost, unavailable, or unusable.
- **Interception:** an unauthorized party has gained access to the information.
- **Modification:** an unauthorized party not only accesses but tampers the information.
- **Fabrication:** an unauthorized entity poses as a legitimate user.

The major attacks come from the network because it is the most vulnerable point to intruders. TCP/IP protocol stack does not offer authentication, confidentiality and integrity. The main derived threads are:

- **Portscanning:** sends client requests to a range of server port addresses on a host, with the goal of finding active ports and services available on a remote machine and exploit its vulnerabilities.
- **Fingerprinting:** process of learning what operating system is running on a particular device.
- **Sniffing:** captures each packet in a network and decodes the packet's raw data. Spoofing: attack in which one person or program successfully masquerades as another by falsifying data and thereby gaining an illegitimate advantage. There are several such attacks: IP spoofing, ARP spoofing, DNS spoofing and WEB spoofing.
- **DoS (Denial of Service):** attempt to make a machine or network resource unavailable to its intended users.
- **"Man in the middle":** attacker intercepts all messages going between the two victims and injects new ones.
- **Hijacking:** illegitimate takeover of groups of IP addresses by corrupting Internet routing tables.
- **Firewalking:** technique that aims to determine a firewall ruleset from an external stand point in order to find its vulnerabilities.

9.6.2 Internet protocol attacks

The major vulnerabilities of the main application internet protocols are:

- **HTTP Web service:** main attack point to both, server with DoS attacks and client by the installation of undesired software. It uses plain text communications, therefore it is vulnerable to sniffing attack.
- **SQL data bases:** second most important attack due to data bases are called from Web servers.
- **DNS name service:** relates the symbolic name with the IP address. The main attacks are DNS poisoning, relating names with the attacker IP, and DoS, relating the name with a non-existent IP address.
- **FTP file transfer:** the main vulnerability of the FTP service is the use of no authentication.
- **Telnet remote administration:** all information is sent in plain text, including the authentication which makes it vulnerable to sniffing attacks.
- **SNMP remote management service:** access to SNMP tools means access to system management. It is important to define proper access permission.

9.6.3 Web architecture attacks

Web architecture consists of a client and a server interchanging information and it is subject to many attack points: client, connection, Web server, Web application and data base.

- **Client attacks:** those that can be performed on an operating system, such as trojan horses, cookie stealing, DNS spoofing and “man in the middle” attack.
- **Communication attacks:** communication is vulnerable to sniffing attacks against the authentication, hijacking and DoS attack.
- **Web server attacks:** attacks are due to the sever version, lack of patches and upgrades and incorrect configuration.
- **Application Web attacks:** safe programming to prevent code modifications, hidden field modification, brute-force attacks to the authentication and malicious code insertion.
- **Data base attack:** data bases are vulnerable to the interception and tampering of the communication, attacks from IPs outside the Web server or attacks to obtain other data bases information.

9.6.4 Security techniques

Security techniques are applied to prevent from the attacks defined.

9.6.4.1 Firewalls

Security system that controls the incoming and outgoing network traffic based on applied rule set. The functions of a firewall are:

- System protection.
- Network separation.
- Control points establishment.
- Information collection.

Firewalls are classified differently according to their characteristics:

- Hardware / software.
- Corporate / personal.
- Commercial / freeware.

Different kinds of filtering are performed:

- **Packet filtering:** works between the network and the physical layer. High performance.
- **“Stateful” filtering:** operate up to layer 4 (transport). High performance and higher security.
- **Application filtering:** comprises all OSI layers. Maximum security and low performance.
- **Multilevel filtering:** mix with the state and application filtering. Maximum flexibility.

9.6.4.2 Virtual private networks

VPN enables a computer to send and receive data across shared or public networks as if it is directly connected to the private network, while benefiting from the functionality, security and management policies of the private network. VPN allows point-to-point encryption and offers:

- **Confidentiality.**
- **Authenticity.**
- **Integrity.**

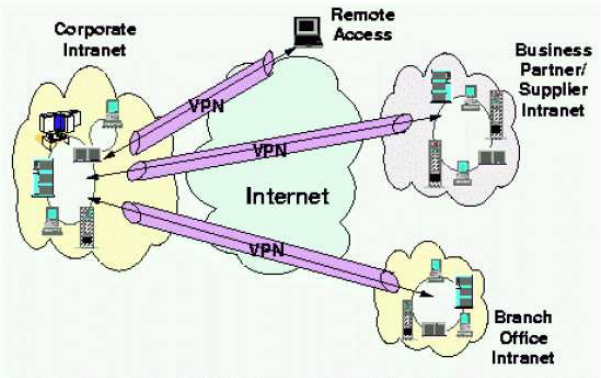

Figure 55: Virtual Private Networks

Protocols used to create a VPN are: IPSec, SSL, TLS, SSH, L2TP, PPTP, ect., which enable:

- **Tunnelling, sensitive traffic encapsulation.**
- **LAN access to mobile terminals.**
- **WLAN access.**

9.6.4.3 SSL

SSL (Secure Socket Layer) is a cryptographic protocol designed to provide communication security over the Internet. SSL provides to a communication:

- Confidentiality.
- Integrity.
- Authenticity.

SSL uses certificates and asymmetric cryptography to authenticate the party with whom it is communicating, and to exchange a symmetric key. This session key is used to encrypt data flowing between the parties.

9.6.4.4 Information encryption

Information is encrypted to prevent a third party the access to it.

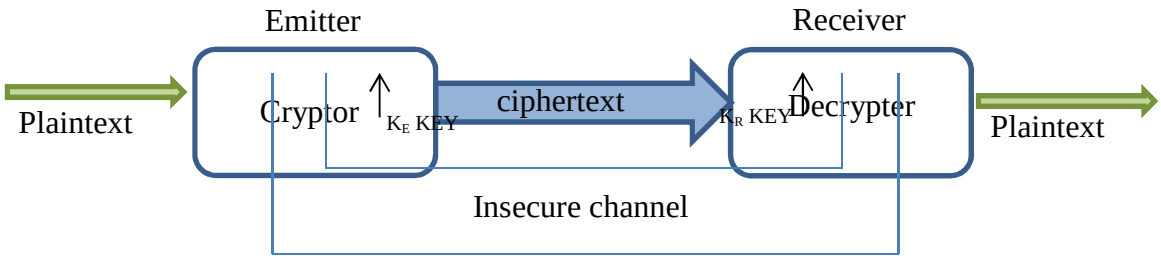

Figure 56: Scheme of information encryption

9.6.4.5 Block cipher vs Stream cypher

Block cipher operate on fixed-length groups of bits, called blocks, with an unvarying transformation that is specified by a symmetric key.

In Stream cipher plaintext digits are combined with a pseudorandom cipher digit stream (keystream). In a stream cipher each plaintext digit is encrypted one at a time with the corresponding digit of the keystream, to give a digit of the ciphertext stream.

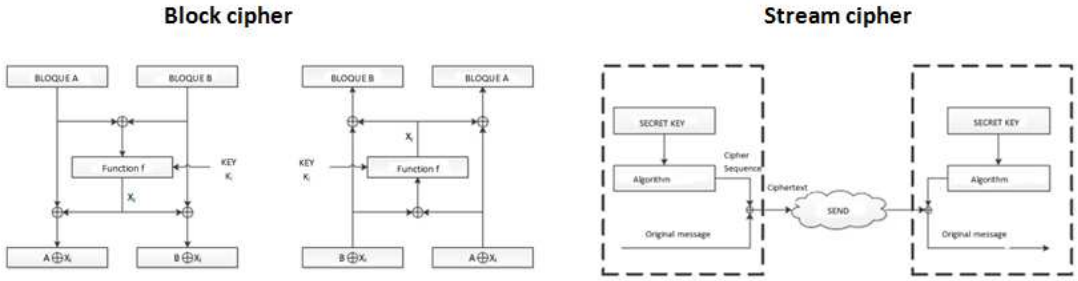

Figure 57: Block cipher vs. Stream cypher

9.6.4.6 Secret key cipher vs public key cipher

Secret key cipher uses the same cryptographic keys for both encryption of plaintext and decryption of ciphertext.

- Very fast, intuitive and secure.
- Always require that the key remains secret.
- Difficulty to exchange the key between emissor and receiver.
- Examples: DES, Tripe DES, AES.

Public key cipher requires two separate keys, one secret and one public. The two parts of this key pair are mathematically linked. The public key is used to encrypt plaintext or to verify

a digital signature; whereas the private key is used to decrypt ciphertext or to create a digital signature.

- Solves the key exchange problem.
- Digital signature possibility.
- Computationally and heavy algorithms.
- Examples: Diffie-Hellman, RSA.

9.6.4.7 Other security technologies

Other technologies may be taken into account:

- The use of a proper topology and routing decisions affect to the link availability and integrity.
- Redundancy increases security.
- Internal firewalls.
- Unused ports and services disabling.
- Use of secure protocols.